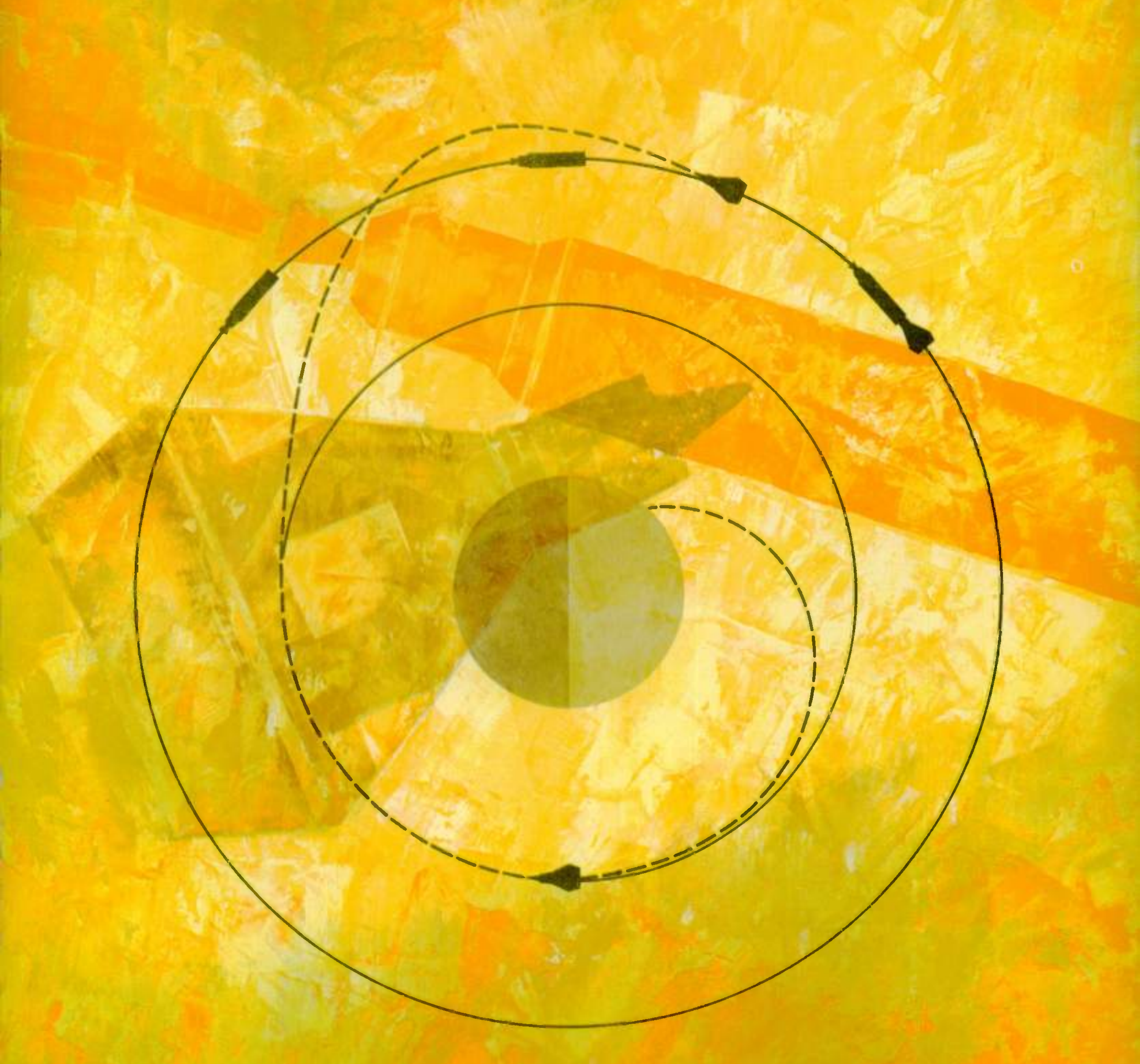
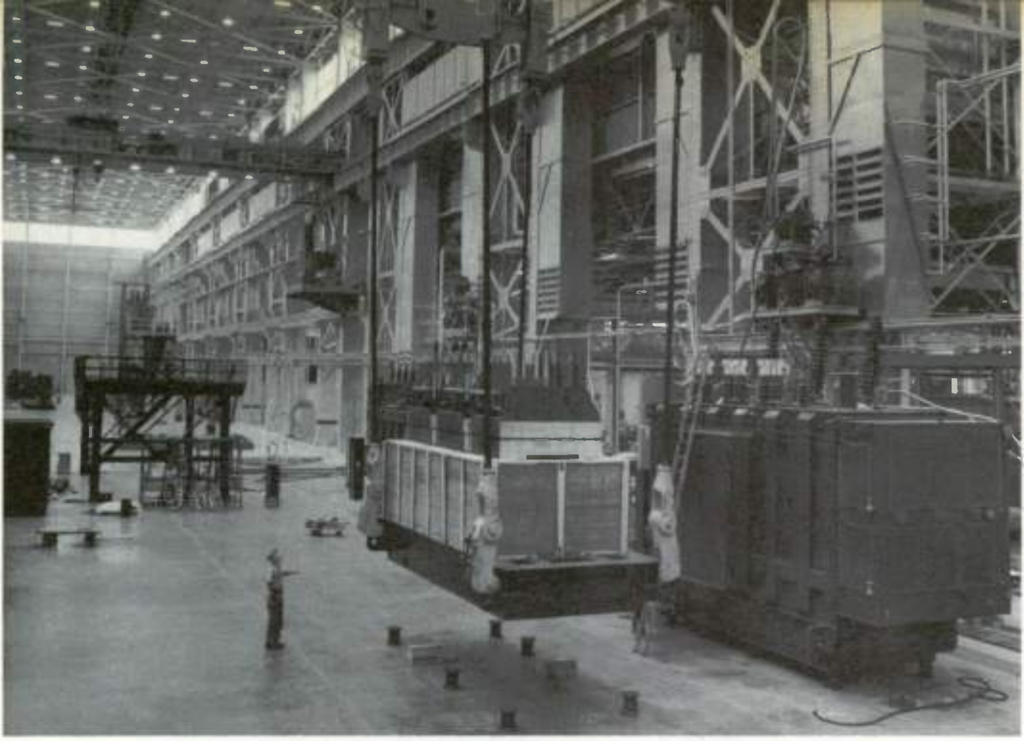
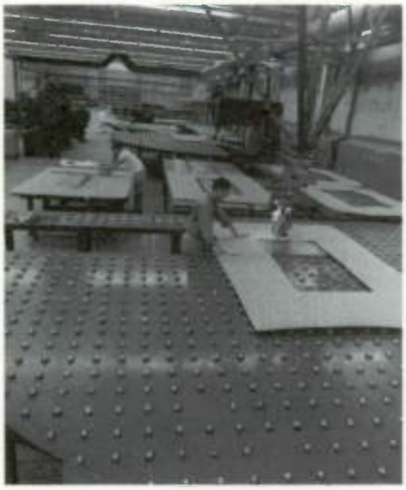
Westinghouse ENGINEER

JULY · SEPT. 1962





scenes from a new transformer plant



The design of a huge new testing transformer is discussed on page 119 of this issue. Two of these transformers are now installed in a new power transformer plant at Muncie, Indiana. The photos on this page show some of the other facilities at the new plant, which has the capacity for building three-phase transformers, in single units, up to 1 000 000 kva, and single-phase units up to 500 000 kva.

Above, when the core and coil assembly has been completed, the unit is moved to a "fit-for-test" area by an overhead crane. Here all the remaining assembly is performed prior to final testing.

At left, part of the operations on pressboard insulation are shown. The pressboard is sheared square and to size, then conveyed to the layout table in the background. Here it is manually laid out with templates and straightedges. The washer is then transferred to the throatless jigsaw in the foreground, where it is cut to contour and size and the window opening removed.

Below, a completed cooling radiator is shown on a test fixture. Here the radiator is tested with hot oil under 40 psi for 30 minutes, then rotated and tilted for draining.

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Cover Design: Space rendezvous will probably be one of man's next major accomplishments in his efforts to conquer space. This month's cover diagrams the rendezvous symbolically against a background of the space vehicles. The cover was designed by Gene Gogerty of Ad-Art Studios, Pittsburgh.

editor
Richard W. Dodge

managing editor
Matt Matthews

assistant editor
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design and production
N. Robert Scott

editorial advisors
R. V. Gavert
J. A. Hutcheson
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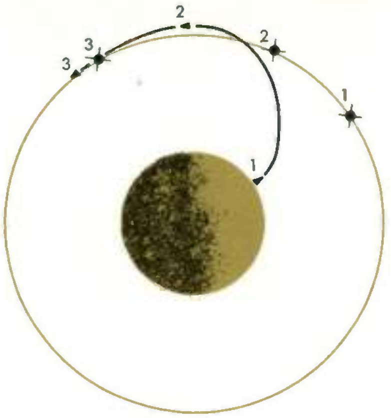

1 LAUNCH AND MID-COURSE 2 TERMINAL 3 DOCKING

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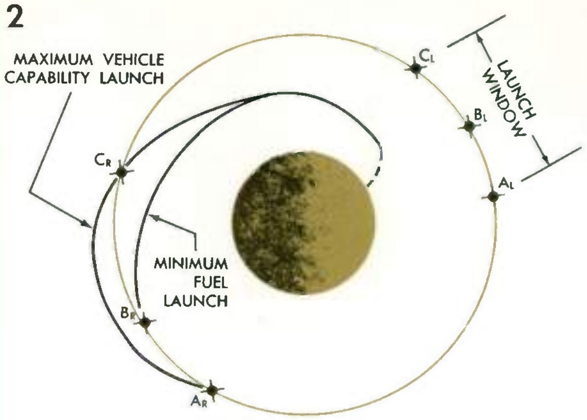


Space Rendezvous Guidance and Docking Techniques

Charles I. Denton, Senior Engineer
Robert M. Sando, Fellow Engineer
Mechanical Design and Development

Arthur T. Monheit, Fellow Engineer
Systems Formulation
Air Arm Division
Westinghouse Electric Corporation
Baltimore, Maryland

Bringing two objects together in space, while they are traveling at some 17 000 miles per hour, obviously presents problems. Herewith, a general discussion of some rendezvous and docking techniques now under consideration.

A major technological step required for progress in space exploration is a practical, workable satellite rendezvous technique. Satellite rendezvous involves the controlled launch, ascent, and physical coupling of a chase vehicle with a target satellite already in orbit.

Satellite rendezvous will have many uses. In the near future, it could provide a means for obtaining maximum utilization from small boosters. For example, a manned lunar mission could be accomplished by rendezvousing two vehicles in an earth orbit—one a fuel tanker and the other a manned lunar capsule and a partially filled fuel tank. The manned lunar vehicle could be refueled and launched from orbit towards the moon.

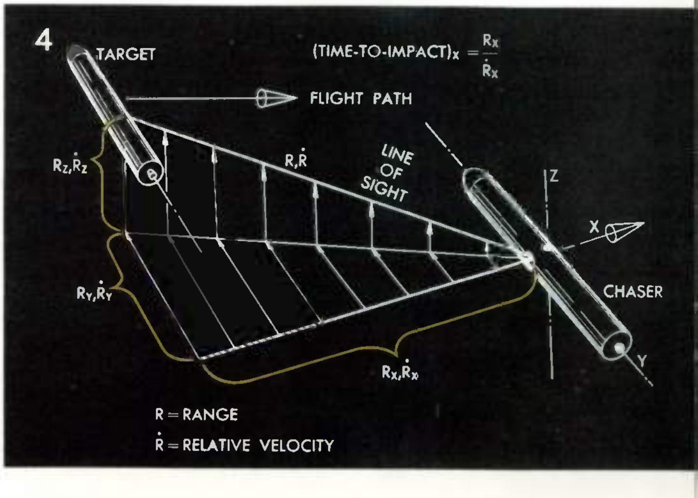
On a much longer range basis, a lunar rendezvous could save payload. A main earth-moon spaceship could be "parked" in a lunar orbit while a manned landing vehicle descended to the moon's surface. When the mission was completed, the smaller craft would rejoin the main vehicle.

Future deep space exploration will probably be made by large vehicles driven by electrical propulsion engines. While such propulsion is economical for outer space work,

Fig. 4 Variable time-to-go terminal guidance directs terminal maneuvers along the three major axes of the chase vehicle.

Fig. 5 When the chase vehicle reaches the computed variable time-to-go line of 300 seconds, thrust is applied to lower closing velocity. An integrating accelerometer measures the reduction in closing velocity and at a predetermined point, the engine shuts off and coasting begins. The cycle is repeated when the newly computed 240-second time-to-go is reached. The forbidden zone is the region in which decelerating thrust is insufficient to prevent damaging collision.

Fig. 6 Satellite docking uses relative position between target and chaser as the basic reference.



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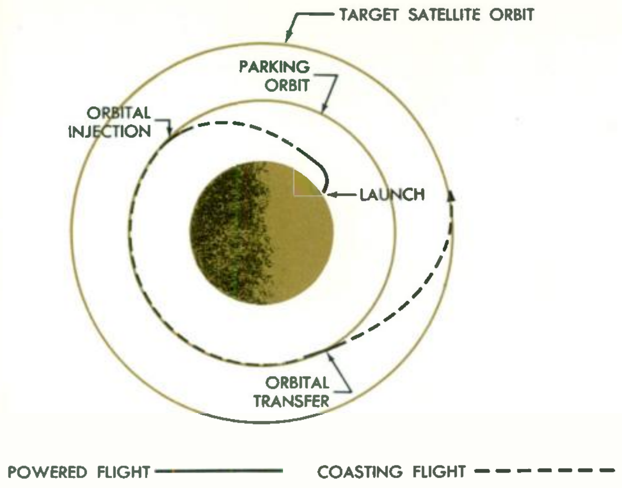


Fig. 1 The launch and mid-course guidance phase of a satellite rendezvous system starts at 1 and is completed when the chaser vehicle is some 50 to 100 miles *ahead* of the target satellite at 2 with a closing velocity between chaser and target of 500–2000 feet/second. (The chaser is put up ahead of the target at a slower velocity and the target allowed to catch up. To put the chaser behind, the chaser would have to speed up and then slow down, which would be wasteful of fuel.) The terminal guidance phase brings the two vehicles to close proximity, say 500 feet apart, with some 5–10 feet/second residual closing velocity. The docking phase completes the rendezvous with a mechanical coupling of the two vehicles at 3.

Fig. 2 Direct ascent paths for minimum fuel and maximum vehicle capability launch. The latter will determine the size of the launch window.

Fig. 3 Launch window limitations can be minimized by placing the chase vehicle in a parking orbit, where it can be accelerated to the target satellite orbit at the proper time.

such engines have very low thrust. These space vehicles will have to be boosted into earth orbit by conventional liquid or solid rockets, and assembled in space.

Plans are presently underway to put a permanent earth satellite into orbit for use as a space test station. Here flight crews could be trained for future lunar and deep space missions. Zero gravity and high vacuum would provide the necessary environment for testing space suits, life support systems, propulsion systems, etc.

As the frequency of manned earth orbital launches increases, so will the chance for an equipment breakdown, preventing the astronaut's re-entry. A rescue system is needed with satellite rendezvous capability and, of course, the ability to subsequently re-enter the earth's atmosphere.

When the unmanned satellites become large enough, it will become economical to send a rendezvousing satellite up for repair purposes, rather than put a new satellite into earth orbit.

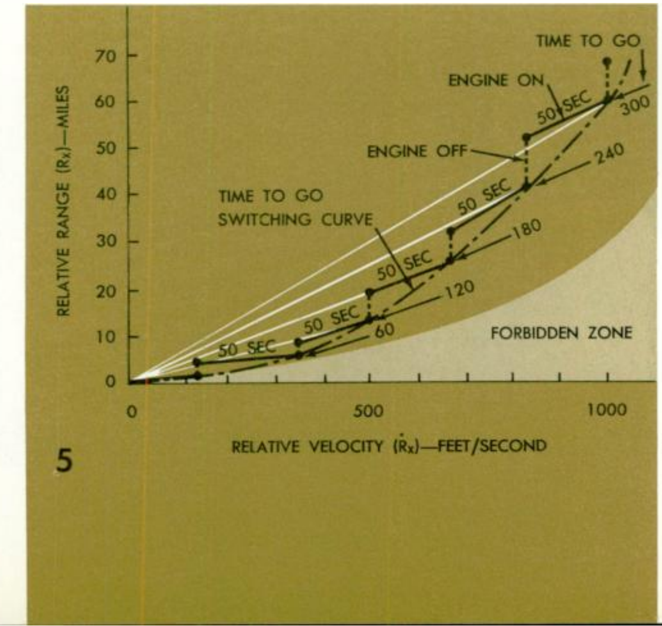
A system capable of inspecting satellites of unknown origin is needed. Westinghouse Air Arm Division is presently contracted to provide the guidance rendezvous sensor suitable for such an inspection application.

With these anticipated uses of satellite rendezvous in mind, engineers at the Air Arm Division have been conducting a two-year study program; the following ground rules have guided the study:

1. The target was assumed to be cooperative, i.e., it could employ radar or optical sensors of its own, exercise appropriate maneuvers (although it was restricted to simple rotational movements), and incorporate part of a docking mechanism. This leaves open the question of the rescue mission, where the target satellite could be friendly but not necessarily capable of being cooperative.

2. The rendezvous method should be adaptable to automated operation. For example, in a multiple refueling mission the crew probably would not be put in orbit until the final rendezvous.

3. The vehicle performing the rendezvous mission should be of useful size. Payload transfers as high as 50 000 pounds were postulated for the study. The actual number is not critical since engine size, fuel consumption, etc., vary with payload weight; however, the rendezvous guidance sensor



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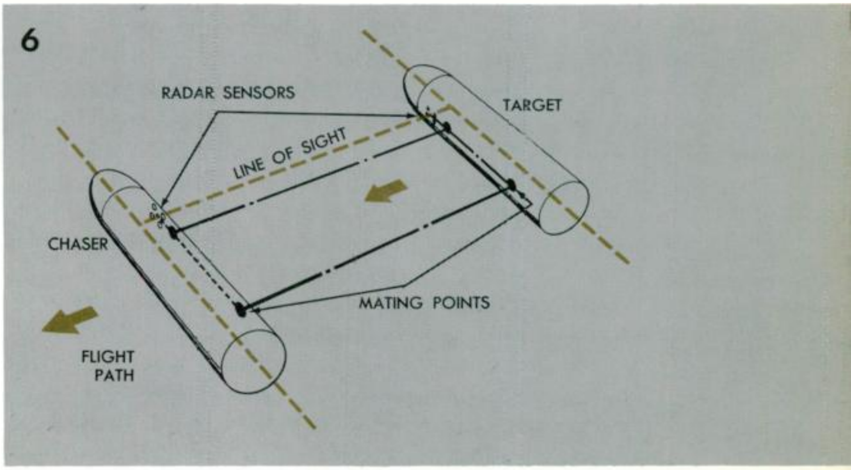


is completely independent of the space vehicle size.

The results of this program have been applicable ideas and techniques for a system capable of performing cooperative rendezvous.

Launch and Mid-course Guidance

The basic phases of a satellite rendezvous system are shown in Fig. 1. Complete knowledge of the target satellite orbit is needed to determine launch time and mid-course path of the chase vehicle. Generally, the chase vehicle will be launched when the orbital plane of the target is nearly coincident with the launch station. This opportunity exists twice a day if the latitude of the launch station does not exceed the inclination angle of the target orbit. For launch stations at greater latitudes, an in-plane launch is impossible, and rendezvous can be accomplished only by an orbital transfer to the target orbital plane. (An orbital transfer for a difference in inclination angle of only 10 degrees at a 300-mile altitude would require 3500 pounds of fuel for a vehicle initially weighing 10 000 pounds in earth orbit.)

In addition to an in-plane launch, the target satellite must be in a position that nearly coincides with the ascent trajectory of the chase vehicle. Of the innumerable ascent paths possible, two represent a minimum fuel and a maximum vehicle capability launch (Fig. 2). The spread between possible satellite positions at time of launch is known as the *launch window.* The greater the vehicle capability the larger the launch window. For reasonable vehicle capabilities, launch windows are small—only a few degrees of orbital arc.

The small launch window places a stringent requirement on launch time. For example, a satellite at a 300-mile altitude travels 4 degrees per minute; therefore, for a 4-degree launch window, the time of launching must be held to within one minute.

The size of the launch window can be increased by first launching the chase vehicle into an orbit of lower altitude than the target satellite. In this "parking" orbit, the chase vehicle has a higher angular rate than the target satellite and will gain on the target satellite, placing itself in a favorable position for orbital transfer to target satellite altitude, as shown in Fig. 3.

The launch and mid-course guidance phase places the chase vehicle in the neighborhood of the target satellite. At this time the chase vehicle is approaching its apogee and has separated from its booster stage. Since ground track sensing is inadequate to determine terminal guidance maneuvers, the terminal flight path must be determined by a sensing and computing system in the chaser and target satellites.

Terminal Guidance

Engineers selected a variable time-to-go guidance technique to direct terminal maneuvers. The chase vehicle is stabilized with respect to the horizon; its main thrust engine is aligned along the orbital path so that it can accelerate the chase vehicle to orbital velocity. The terminal guidance sensor measures range, closing velocity, and bearing angle to the target (Fig. 4). The ratio of range to closing velocity provides the time-to-go indication. As shown in Fig. 4, these values are resolved along the three major axes of the chase vehicle. Nongimbaled, fixed-thrust engines are operated in an on-off mode to reduce closing velocity to zero in finite steps as time-to-go approaches zero along each axis.

The terminal guidance program shown in Fig. 5 illustrates the braking principle. Only the vehicle axis along the orbital path is shown. Rendezvous begins at a range of 70 miles and a closing velocity of 1000 feet per second. The program shown in Fig. 5 takes the chase vehicle to a range of 500 feet and a closing velocity of less than 10 feet per second. (These latter points are too close to the origin to be shown in the figure.)

Range, closing velocity, and bearing angles are determined by a radar sensor; radar was selected over optical methods because of well-developed ranging techniques and a negligible sun and background problem. To perform this task engineers developed a unique interrogator-transponder pulse type radar. A transponder is located on the target satellite to reply to the radar interrogating signal. This technique minimizes the transmitting power needed for initial detection. Non-gimbaled spiral antennas are used to measure bearing angle by interferometer techniques. These two techniques make possible a radar and transponder that weigh only 32 pounds and draw 42 watts of primary power. An active system with gimbaled antennas would weigh over 200 pounds and require 2.5 kilowatts of primary power. The reduction in weight and complexity achieved by this design have produced an attendant increase in reliability.

Satellite Docking

The terminal guidance phase ends and the docking phase begins when the two vehicles are 500 feet apart. This distance permits transfer to the docking guidance mode at sufficient separation to avoid inadvertent collision from terminal guidance errors. In docking, the *relative position* between target and chaser becomes the basic reference so that proper orientation of each satellite can be provided for docking.

The transition to docking is initiated by the chaser and target satellites aligning themselves, by means of rotational movements, so that the two vehicles are perpendicular to the radar line of sight, with the long axis of the vehicles stabilized to the horizon. This is shown in Fig. 6 for side-to-side docking.

Once the vehicles are aligned they are maintained parallel; deviations off the line of sight are detected by the radar sensor and corrected by translational movements of the chase vehicle; the target maintains its attitude by purely rotational movements. Translational movements are used only by the chase vehicle so that cross coupling problems can be minimized.

Closing velocity is reduced and held between 1 and 4 feet per second. The control actuation of range and angle movement is performed by small attitude jets. Main thrust engines are no longer needed, obviating the problem of rocket flame damaging the target. When range is reduced to 5 to 10 feet, physical coupling is made between vehicles by a mechanical docking mechanism.

The basic sequence for physically coupling the satellites, regardless of docking configuration (side by side or end to end), are as follows:

1. Align vehicles
2. Couple vehicles at close range
3. Absorb energy of docking at first contact
4. Absorb energy of rebound
5. Bring vehicles in contact with aid of coupling mechanism
6. Engage the mechanism necessary to accomplish the mission

Close range coupling prior to contact prevents separation after the docking impact. Otherwise, separation would require additional fuel expenditure to attempt a second rendezvous. Energy absorption at first contact and at rebound are necessary to dissipate the momentum of the closing vehicles. To absorb initial contact energy, absorption material can be placed on the impact surface of the chase vehicle, which will contact a hard surface on the target vehicle. The maximum closing velocity will determine the energy absorption requirements. The docking mechanism must have built-in capability to absorb rebound energy.

After rebound energy has been absorbed, the vehicles will be standing apart and must be brought together with a drive on the coupling mechanism. Transfers between vehicles will be accomplished by such mechanisms as vehicle-to-vehicle couplings to allow fuel transfer to the target vehicle, airlocks for transfer of personnel, or a coupling arrangement for the addition of booster sections.

After the mission is accomplished, the vehicles can be separated by releasing the coupling mechanism and applying a thrust from the attitude stabilization jets. Separation should be accomplished so that the target vehicle can accept multiple rendezvous.

Docking Techniques

Many techniques are possible for accomplishing the docking sequences. Some factors that should be considered in selecting a system are: weight, reliability, suitability for use with space vehicles, capability of accomplishing the mission, and compatibility with other rendezvous systems (guidance and control, etc.).

The basic docking method should be capable of coupling the two space vehicles side by side or end to end. Advantages and disadvantages exist for each technique. The basic components of docking hardware required for the chase vehicle are the coupling mechanism and its associated controls, energy absorbing material, drive mechanisms, and tow line. The target vehicle will require some form of coupling mechanism receptacles and a hard surface at the contact area.

Other components not required for the actual docking operation but needed for specific mission operations include air lock mechanisms, fuel transfer systems (pumps, tanks, connectors, etc.), mechanical and electrical connectors, etc. Additional structural parts, such as frames and stiffeners, may be required to transfer impact loading to the major structural members of the space vehicles.

One possible method of docking is illustrated in Fig. 7. Explosive bolts hold cover plates over cavities in the chase vehicle. Each cavity contains an inflatable hose and end cap structure. During ground installation, the tube assembly (including the end cap structure) is pumped nearly free of air. Upon release of the cover plates, the tube is in-

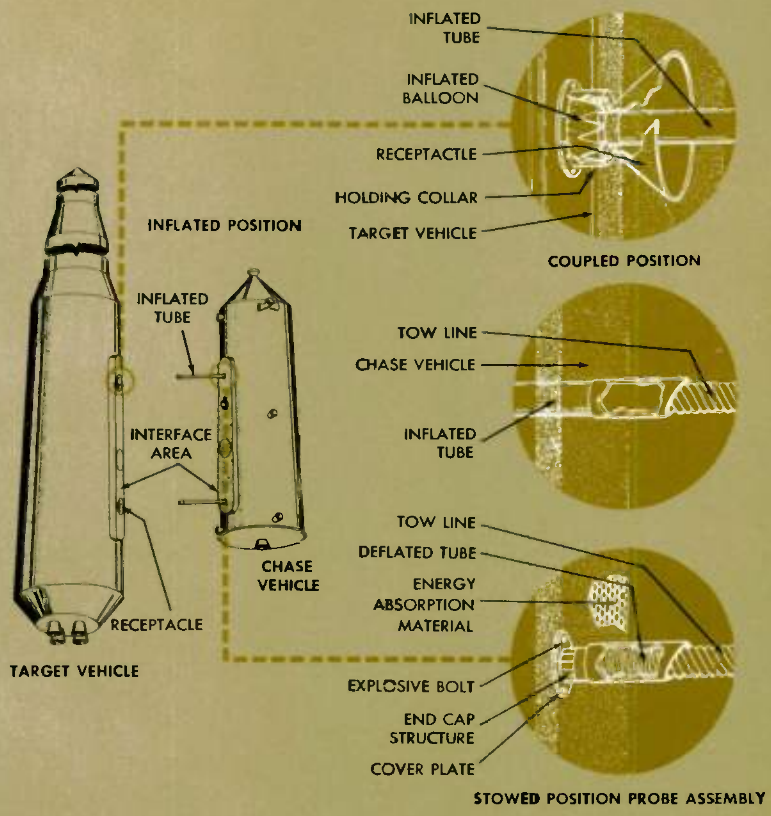
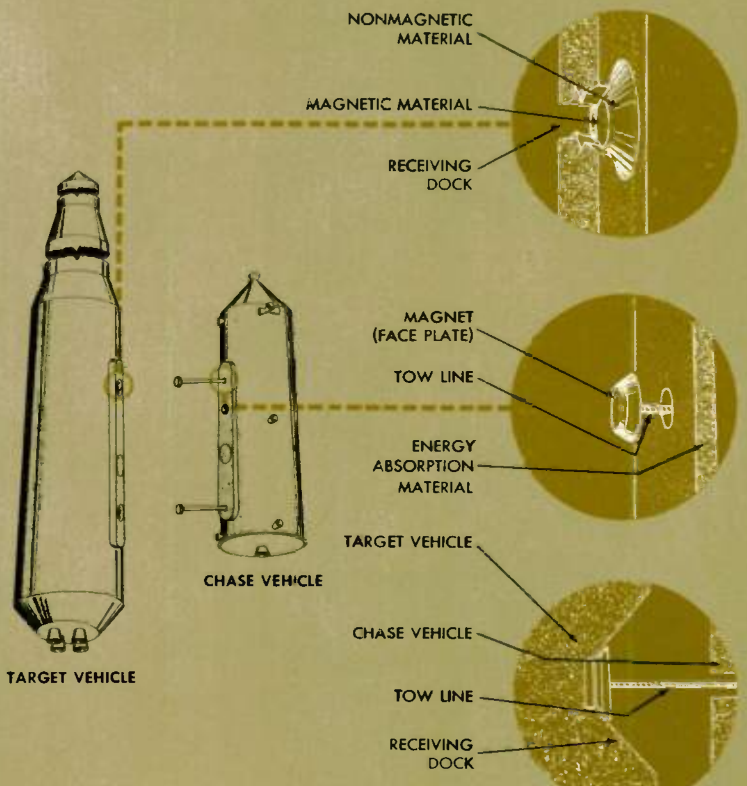


Fig. 7 Docking mechanism details are shown for an inflated-tube method of physical coupling between chase and target vehicles.

Fig. 8 Docking mechanism details are shown for a magnetic clamp method of physical coupling between chase and target vehicles.



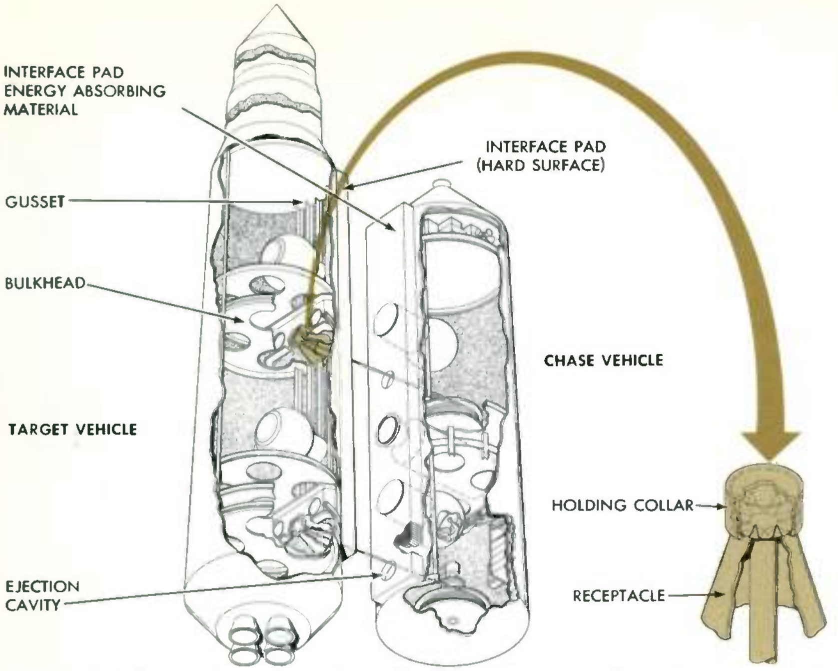


Fig. 9 Details are shown for side-to-side satellite docking. Six bulkheads react the lateral or beam loads acting on the interface pad. Gussets and intercostals provide the necessary local stiffness and strength. The shear loads induced in each bulkhead are reacted by the shear tie between the bulkhead and outer skin of the space vehicle. During rebound, the bulkheads adjacent to each of the receptacles react the tension loads generated within the holding collar.

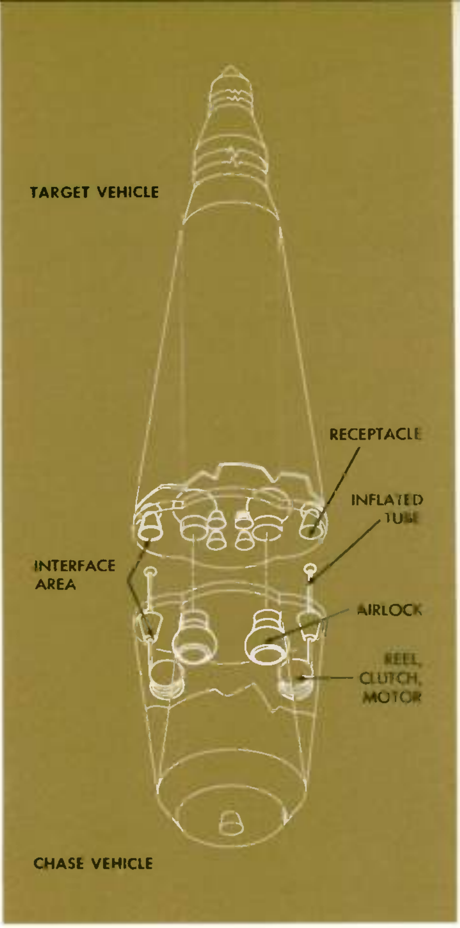


Fig. 10 End-to-end satellite docking may be most practical in some cases.

flated by the small amount of residual air, so that an inflated tube and end cap structure protrude from each of the cavities. This action takes place at a distance between vehicles greater than 10 feet. The end cap of the tube enters the funnel-shaped receptacle in the target vehicle. This receptacle must be large enough to offset allowable guidance errors of the radar and control system. The end cap structure consists of an inflatable balloon, contained within a series of hinged curved segments that make up a cylindrical tube. The assembly is held in place by an explosive bolt arrangement. As the end cap assembly passes into the throat of the receptacle, it intersects a magnetic field in the target vehicle. A sensor located in the lower section of the end cap structure is activated by this magnetic field and triggers the explosive bolt, causing the balloon to inflate. This forces the hinged segments to a position shown in Fig. 7. The balloon assumes the shape of the cavity and provides the necessary pressure loading to establish the required tow line between the two vehicles before impact.

When the balloon, housed in the end-cap structure, is inflated, a sensor activates a drive reel in the chase vehicle (Fig. 9) and the tow line slack is taken up. When the vehicles impact, the energy absorption material on the chase vehicle removes most of the kinetic energy. The rebound energy is dissipated by a torque-limiting clutch, which limits tension loads on the inflated tube and end cap structure. When the vehicles come to rest, a speed-controlled motor reels the tube in, bringing the vehicles together.

Vehicle separation is accomplished by deflating the tube end-cap balloon, reeling it into the chase vehicle and activating the propulsion system.

Another possible docking technique employs a magnetic clamp or plate, which is guided into a receiving dock fabricated from magnetic material (Fig. 8). The docking methods shown describe only two of several that were developed during the study.

Side-by-side docking has an advantage over end-to-end docking because it provides a larger interface area for energy absorption material, mechanical and electrical connectors, cargo or personnel transfer, refueling lines, etc. Side-by-side docking would provide a feasible means for building a cluster of modules for eventual rendezvous with a space-craft unit.

Since the majority of space vehicles are designed primarily to resist end loads, it is necessary to include additional bulkheads, stiffeners, intercostals, gussets, etc., in the spacecraft for side-by-side docking. With the proper design, loads can be transferred from the impact area to the spacecraft structure. One method of reinforcing such a structure is shown in Fig. 9.

End-to-end docking (Fig. 10) requires a minimum of additional structure; the structure that has been designed to withstand the launch and boost acceleration loads should be nearly sufficient for reasonable levels of impact loading. End-to-end docking provides a means for adding modules in series to a space vehicle.

The mechanical design of a satellite docking mechanism is dependent, to a large extent, on the requirements of the space vehicles being docked. The docking phase can be mechanized in many ways; the choice will be determined by such considerations as suitability for use with space vehicles, capability of accomplishing the rendezvous mission, weight, and reliability.

Steam Turbine-Generator Automation

E. G. Noyes and R. L. Richards
Large and Medium Turbine Department
Westinghouse Electric Corporation
South Philadelphia, Pennsylvania

J. D. Davidson
Large Rotating Apparatus Department
Westinghouse Electric Corporation
East Pittsburgh, Pennsylvania

Much of the engineering effort that goes into designing an automated steam plant consists of developing or adapting the turbine-generator unit and its control functions for digital computer supervision.

Complete steam plant automation requires a control system with ability to sense hundreds of conditions, and to adjust many devices to maintain the proper level of all plant-controlled variables. Automatic controls for turbine-generator units introduced in the past have been relatively simple, since each has depended on a minimum number of controlled and manipulated variables. The transition from these individual automatic controls to complete digital computer control is not yet clearly defined. Some designers advocate that all control functions should be handled directly by the computer; others believe that the application of subcontrol loops, with computer-adjusted setpoints, should be extended. The philosophy will undoubtedly crystallize as operating experience is obtained and new ideas materialize.

In the development of an automatic steam plant to operate in this fashion, turbine and generator design engineers have the following responsibilities:

1. Select and apply reliable sensing devices.
2. Adapt existing subcontrol loops for automatic computer monitoring and control, and develop new subcontrol loops for critical turbine-generator functions to provide independent control and protection for the equipment.
3. Establish operating logic sequences suitable for computer programming covering normal and contingency conditions.
4. Establish reasonable limits for the turbine generator unit variables that are critical to assure long life of this equipment.

Turbine Considerations

The computer must monitor many variables when supervising the control of the turbine during transient speed and load operation. The choice of variables to be monitored

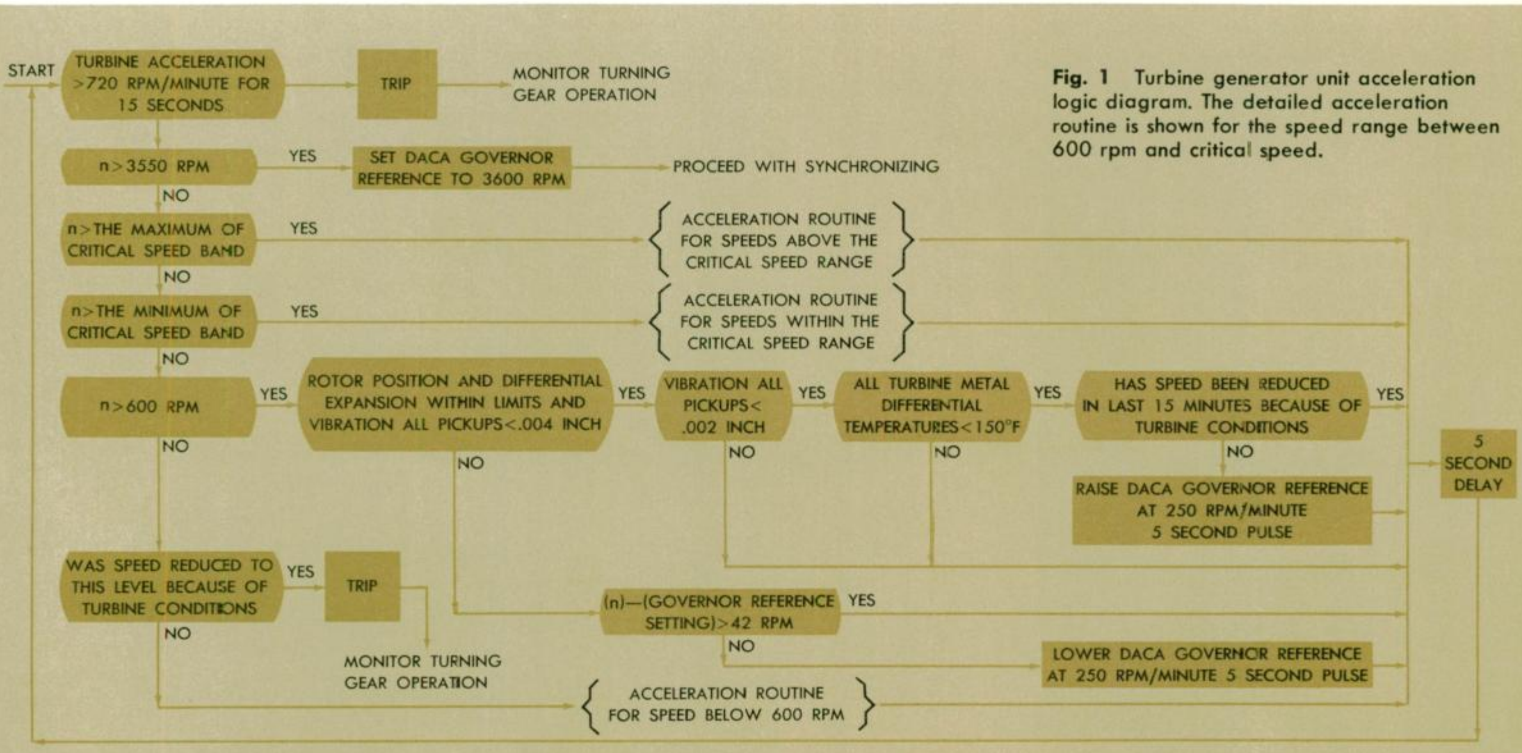


Fig. 1 Turbine generator unit acceleration logic diagram. The detailed acceleration routine is shown for the speed range between 600 rpm and critical speed.

is based on past operating experience and design criteria. Many units installed in the last ten years have the necessary instrumentation to give the operator a record of these variables. Some of the variables are: Rotor eccentricity and vibration; rotor-casing differential expansion; rotor position; and cylinder expansion.

In addition to these, turbine temperature distribution is an important variable. Extreme values of eccentricity, vibration, and differential expansion are usually caused by abnormal temperature distribution. Severe temperature transients can produce conditions that can be anticipated and controlled, such as: high thermal stress of thick wall stationary parts, which can cause temporary or permanent distortion; excessive differential expansion, which can produce a rub and cause rotor vibration; and abnormal radial and axial temperature gradients in the turbine rotor, which cause additional rotor stress.

The basic instrumentation and the limits are selected to anticipate these conditions. The following requirements represent the minimum:

1. Prior to admitting steam to the unit, the superheater outlet temperature is controlled to a value that depends on throttle-stop valve inner wall and turbine first-stage metal temperature.
2. During starting, the steam flow rate is controlled to limit the temperature gradient across the throttle valve, steam chest, and casing walls.
3. To avoid condensation, prior to transferring to normal governor control, the temperatures of the steam-swept surfaces of the high-pressure inlet features are kept at a temperature higher than the saturation temperature to which these parts will be subjected during subsequent partial admission operation.
4. Since first-stage temperature will increase approximately 250 degrees F from no load to full load (assuming constant inlet temperature), the rate of change of this temperature must be considered.

These turbine requirements are basic factors in the development of operating logic. For example, the operating logic required for control of turbine acceleration during the starting cycle is shown in Fig. 1. This computer program is applicable for hot and cold starts. The routine is shown in detail for the speed range between 600 rpm and critical speed. A similar approach can be used for programs at other speed levels.

The acceleration logic is based on the premise that the unit can be brought to synchronous speed in a minimum time, provided measured turbine conditions are satisfactory. However, if rotor vibration increases above a nominal limit, or if turbine metal temperatures are excessive, the existing speed level is held. Speed is decreased for excessive rotor-casing differential expansion, extreme rotor position, or a further increase in vibration to an abnormal level. If the operating logic calls for a reduction in speed, the reduced speed level is held for fifteen minutes to assure that stable conditions exist before the acceleration program is continued.

The actual deceleration rate of the rotor depends upon its inertia. Therefore, to maintain governor control, the differential between the actual rotor speed and the lowered starting governor reference speed must be limited to a predetermined value.

Generator Considerations

The generator features required for an automated plant are not materially different from those required for normal control. However, some of the auxiliary equipment will be adapted for automatic control.

Present practice, in a large number of utilities, is to record average rotor temperature and readings from a selected number of stator winding resistance temperature detectors. The hot and cold gas temperatures may or may not be recorded. On automated units, where generator loading is supervised by the capability curve limiter and generator cold gas is maintained by a subcontrol loop, the need for recording rotor and stator temperatures does not appear necessary. It would seem more desirable to have the computer periodically compute rotor and stator temperature rises and compare these values to those expected for the particular gas pressure in the machine.

For cross-compound units, normal practice is to synchronize the two shafts at turning-gear speed. However, if the starting procedure is confined to relatively low speed for some reason such as eccentricity, the generator rotor

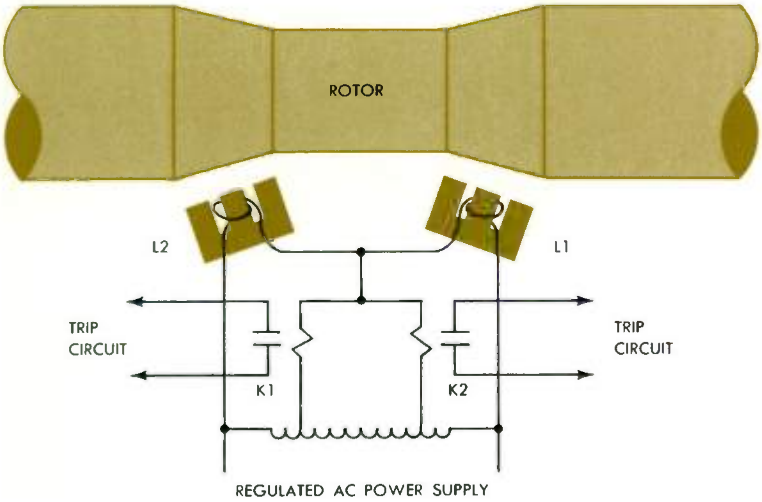


Fig. 2 (Left) Differential expansion trip: Air gaps of pickup coils L1 and L2 are set equal, so that rotor expansion relative to the casing will cause the air gaps to change and unbalance the voltage drop across the operating coils K1 and K2. If rotor motion exceeds a predetermined limit, the voltage drop actuates the turbine trip circuit.

Fig. 3 (Right) Generator capability curve limiter.

temperatures may limit the time that the unit can be held at reduced speed. This is because the generator ventilation system may not circulate enough gas to cool the rotors even though excitation is considerably below rated value. The following procedure will protect the rotors under low-speed conditions: After the generators have been synchronized on turning gear, the acceleration program immediately raises unit speed so that the generator ventilation system can provide sufficient rotor cooling. The minimum speed is a function of the type of generator ventilation employed, and the amount of excitation supplied to each rotor. Representative minimum speeds are between 150 and 350 rpm.

A similar situation exists after a trip out from full- or part-load operation. Some utilities prefer to keep the rotors synchronized, so that the unit can be brought back to rated speed and resynchronized with the system after the trouble has been corrected. If excitation is reduced to the no-load value when the unit is separated from the system, rotor temperature will not be a limiting factor if speed is maintained above the minimum needed for rotor cooling.

SUBCONTROL LOOPS

Most of the normal control functions in automatic plants now being designed are handled by self-contained subloops, which are monitored by the computer. In some cases, the computer adjusts the subloop setpoints as required by conditions existing in the unit. Some of the major subloops being developed for application on the automatic turbine generator unit are:

1. Vibration and differential expansion trips.
2. Generator capability curve limiter.
3. Control of generator gas and seal oil systems
4. Rotor phase position detector.
5. Wide speed range DACA starting governor.
6. Automatic rotor turning gear.

Vibration and Differential Expansion Trips

The vibration and differential expansion trips employ simple circuits completely independent of recording and control instrumentation. Separately guarded pickups employ electromagnetic or static circuitry to insure reliability. The differential expansion trip circuit, shown in Fig. 2, is typical of this approach. The schematic illustration in Fig. 2 shows the electrical function with a conventional relay; actually, static bistable amplifiers are used to energize the trip circuit.

Generator Capability Curve Limiter

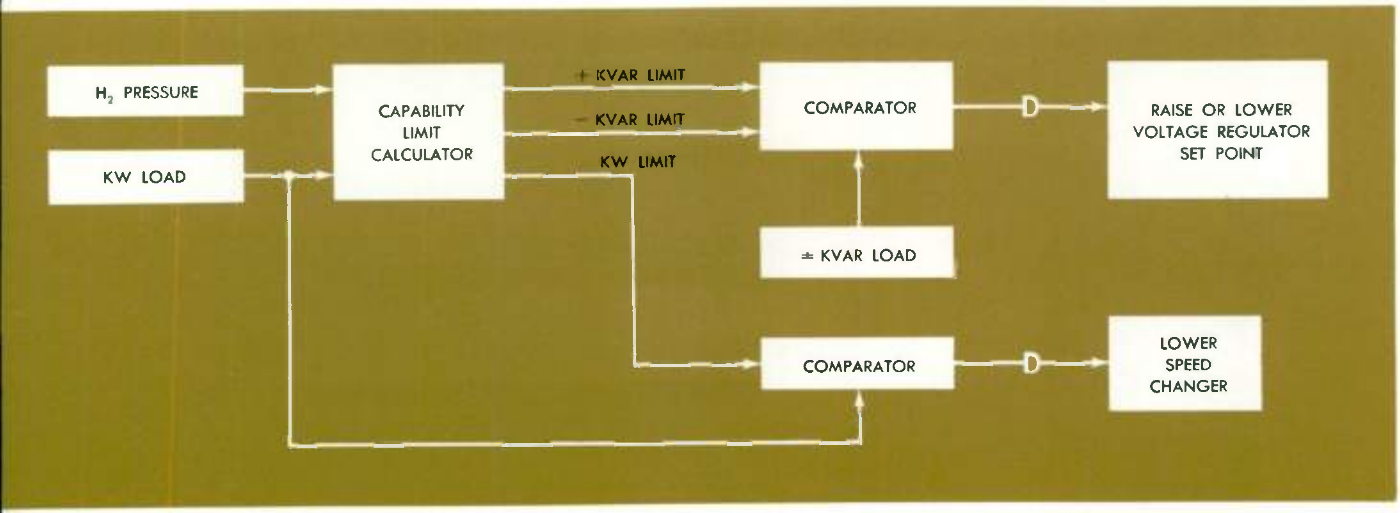
A block diagram of the generator capability-curve limiter is shown in Fig. 3. This device has three input variables: generator kw, kvar, and hydrogen pressure. Output signals go to the generator voltage regulator and the turbine speed-changer motor. For a given hydrogen pressure, this device compares actual kw and reactive loading to the permitted load limits; if either limit is exceeded, except during transient conditions, the capability curve limiter changes excitation and/or governor setting to bring the unit loading back within the curve. The limiter alarms when steady-state loading is within a certain percentage of the limit; this alarm signal indicates that gas pressure should be increased. The system also can be designed to take corrective action.

Control of Generator Gas and Seal Oil Systems

The hydrogen gas system can be arranged in several ways, depending upon installation requirements. If the station is completely automated, the gas system is designed to maintain hydrogen pressure and purity by means of another subcontrol loop. In addition, the generator may be filled with hydrogen automatically with the sequence being initiated by the computer.

After the generator is filled with hydrogen, the control will maintain different levels of purity depending on the availability of certain pumps in the seal oil unit. If purity drops to a hazardous level, the control will trip the unit and purge the generator with CO_2. This feature requires that several thousand cubic feet of CO_2 be available at all times. Also, provision must be made in the gas equipment to prevent CO_2 from freezing in the supply lines.

When the gas system is arranged to fill the generator with hydrogen automatically, an adequate hydrogen supply must be maintained, either by means of bulk storage or a large number of hydrogen bottles connected to a manifold.



Many nonautomated units use this type of hydrogen gas supply system.

Rotor Phase Position Detector

The startup of cross-compound units generally requires that the two generators be synchronized at turning-gear speeds. The application of field current to rotors when their relative phase angles are unknown does not always result in successful synchronization. Therefore, a device has been developed to provide the computer with information on the angular position of the two rotors.

The synchronizing method makes use of turning-gear speeds that provide a slightly different electrical speed for each generator. Hence, the generator rotors will be periodically in electrical phase. The phase-position detector tells the computer when the angular difference is approaching zero, so that generator field currents can be applied, causing the generators to lock in synchronism.

The position-detector sensing device consists of a stationary assembly of encapsulated reed switches, and a small permanent magnet that is mounted on the generator shaft. The circuitry associated with the detector permits excitation to be applied only when the rotors have the correct phase relationship. The switches are operative only during the synchronizing process so that the life of a switch, which is in the order of several million operations, will be comparable to the life of the turbine-generator unit.

In a computer-controlled station, the detector and associated circuitry are arranged as an independent subloop. The computer energizes this subloop and verifies successful synchronization.

Wide Speed Range DACA Starting Governor

The DACA (Digital Analog Control Apparatus) governor is an all-electric static system that was developed several years ago for papermill drive turbines. DACA has an inherent performance advantage over hydraulic governors at low speeds because the gain of the DACA governor is constant over a wide speed range. This characteristic makes the DACA governor ideal for controlling turbines from low to high speeds. Therefore, the same basic design was adapted for the computer-controlled steam electric governor turbine.

The DACA governor, when applied to central station units, can be used as a speed governor or load changer for: (1) speed control from turning gear to synchronous speed; (2) speed control while synchronizing; and (3) load control up to approximately 15 percent of full load.

A block diagram of the DACA governor is shown in Fig. 4. The speed-sensing device consists of a magnetic pickup and a notched disc, similar to a spur gear, mounted on the turbine shaft. When the turbine shaft rotates, the gear teeth induce an ac voltage in the pickup coil. The *frequency* of this induced voltage provides the speed-sensing signal. This ac signal is amplified, converted to a dc voltage directly proportional to frequency, and compared with a reference voltage.

The reference voltage is obtained by rectifying the output of an oscillator. The reference voltage is impressed across a potentiometer so that a reference setpoint can be obtained by positioning the potentiometer. The difference between the speed voltage and the reference voltage is the error signal, which is converted to an equivalent oil pressure for operating the steam turbine throttle valve (See *Operation of DACA Governor*).

The reference potentiometer is positioned by a drive motor, which raises or lowers the selected speed point. The motor is controlled by digital computer contact-closure outputs. Selected contacts cause the motor to operate in the "raise" or "lower" direction, at one of three acceleration rates. The three acceleration rates provide (1) standard acceleration, (2) fast acceleration through critical speed range, and (3) slow acceleration for synchronizing. These acceleration rates may be preset within the range of 100 to 800 rpm per minute.

The application of this wide speed range governor,

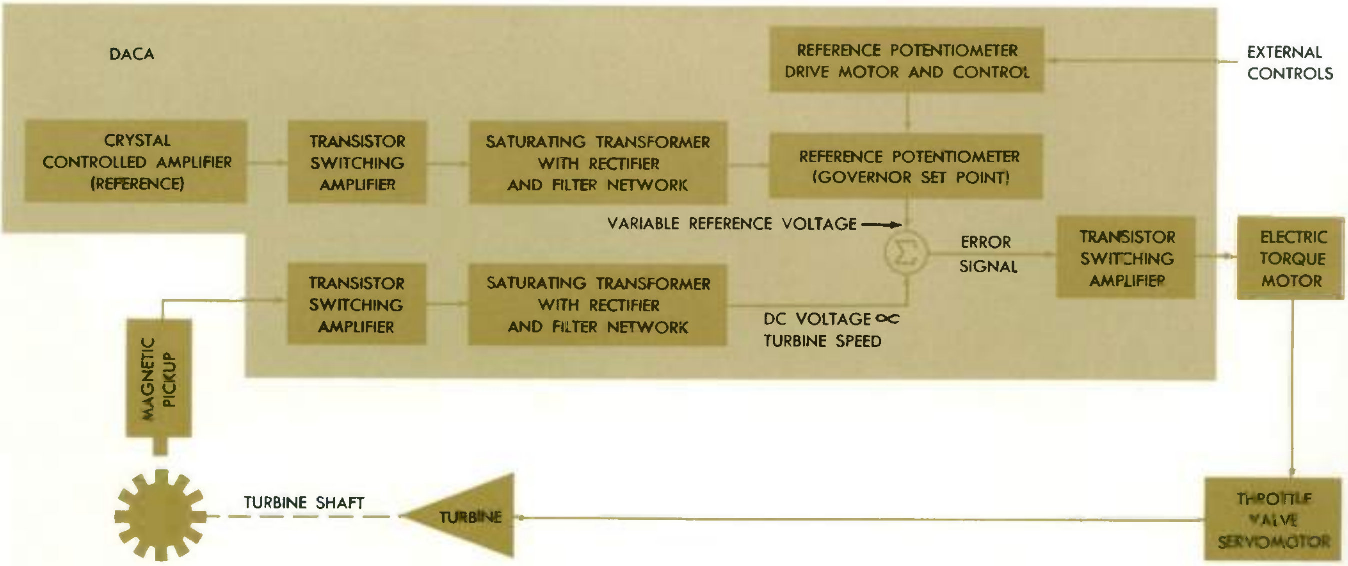
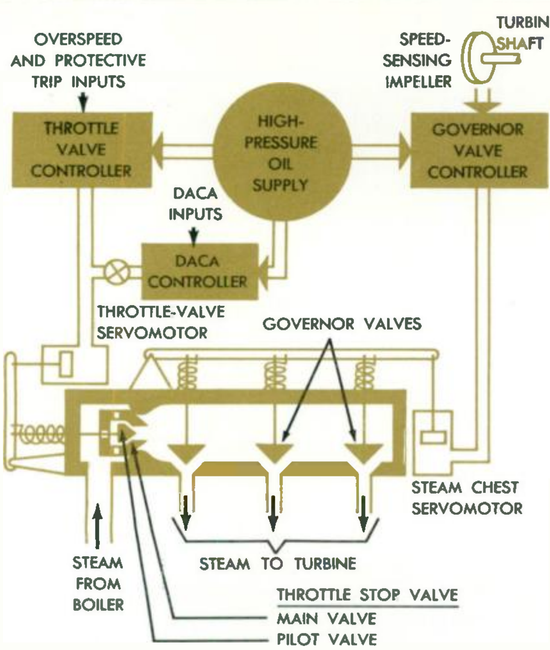


Fig. 4 Block diagram of the DACA governor for turbine speed control.



OPERATION OF DACA GOVERNOR

A typical operating sequence for a DACA governor on a central station turbine can be illustrated with this simplified schematic diagram.

During normal load, turbine inlet steam is controlled by the governor valves. The throttle stop valve is wide open, under the control of turbine overspeed and protective trip devices.

For a DACA-controlled turbine start, the throttle stop valve is closed, and governor valves opened. Control of the throttle valve is transferred from the throttle valve controller to the DACA controller, and the throttle valve controller raised to its maximum open position.

Speed setting of the DACA is increased at its normal acceleration rate until critical speed is reached. Speed is increased through the critical speed range at the fast rate, and changed back to the standard rate when this is accomplished and continued up to synchronous speed. Acceleration rate is changed to slow and the DACA speed setting is moved up or down to synchronize the turbine with the system. After the turbine is synchronized, load is raised to about 15 percent of full load. Load control is then transferred from the DACA controller to the main governor. Throttle valve control is transferred to the throttle valve controllers and the DACA control oil isolated, but the DACA is left energized.

which controls the unit on the throttle stop valves, provides the advantage of starting the turbine with full admission of the governor valves, and allows uniform heating of the high-pressure turbine casing. In the past, the advantage of this procedure was recognized but was limited to starting only since it was not considered advisable to attempt manual synchronizing on the throttle-stop valves as a regular operating procedure since there would be no closed-loop speed control. With the wide speed range governor it will be convenient to synchronize on the throttle-stop valves with full admission and then load to the capacity of the throttle-stop valve internal pilot valves. This load is approximately 15 percent rated load at rated steam conditions. To obtain the maximum benefit from this procedure, pilot valves are used in throttle valves; this arrangement assures that all high-pressure parts are heated as uniformly as possible.

Automatic Rotor Turning Gear

Extension of the remote-operated turning gear to automatic operation was dependent on the successful development of a simple and reliable means of indicating zero speed. This has been accomplished with a hydraulic zero speed device, which produces an elevated pressure when rotation stops. The basic components and the signal characteristic of the zero speed indicator are shown in Fig. 5.

The zero speed indicator and the control components necessary for operation of the turning gear were installed on one of the heater boxes used to establish turbine rotor thermal stability. This installation provided a severe test for these automatic features and demonstrated the design reliability.

Developments in digital computer control techniques are making steam power plant automation a reality. The operational logic needed for computer programming, and the development of subloop controls with operational limits are critical requirements for successful operation of the automatic plant.

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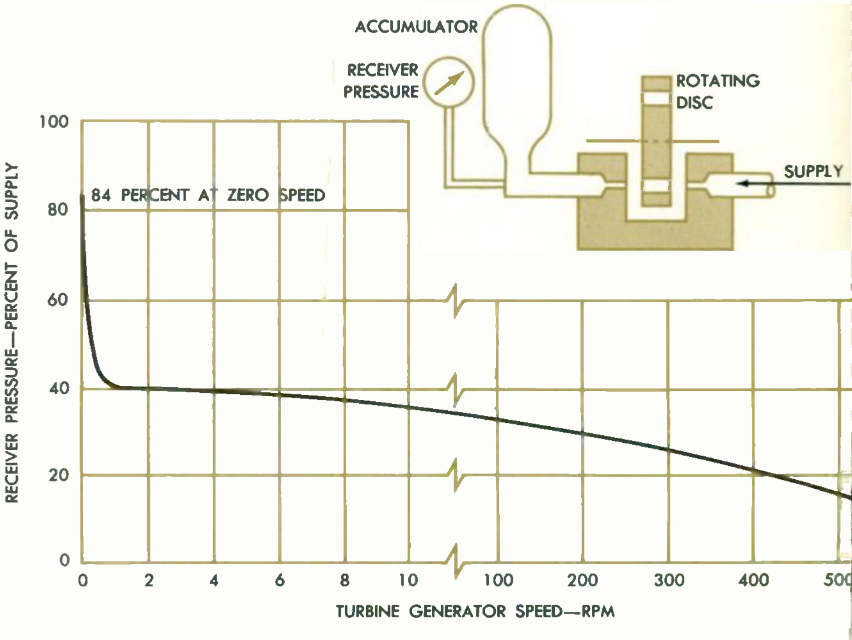


Fig. 5 Rotor zero speed indicator: Two oil supply nozzles discharge to two receivers through circumferential holes in a disc mounted on the turbine rotor. When the disc is rotating, the oil jet is continuously interrupted and the pressure in the receiver is maintained at a low value. When the disc stops, pressure in one of the receivers increases. This oil pressure is the signal used to initiate the automatic turning gear control.

what to report

Technical reports *can* be a useful tool for management—not only as a source of general information, but, more importantly, as a valuable aid to decision making. But to be effective for these purposes, a technical report must be geared to the needs of management.

Considerable effort is being spent today to upgrade the effectiveness of the technical report. Much of this is directed toward improving the writing abilities of engineers and scientists; or toward systems of organization, or format, for reports. This effort has had some rewarding effects in producing better written reports.

But one basic factor in achieving better reports seems to have received comparatively little attention. This is the question of audience needs. Or, expressed another way, "*What does management want in reports?*" This is an extremely basic question, and yet it seems to have had less attention than have the mechanics of putting words on paper.

A recent study conducted at Westinghouse sheds considerable light on this subject. While the results are for one company, probably most of them would apply equally to many other companies or organizations.

The study was made by an independent consultant with considerable experience in the field of technical report writing. It consisted of interviews with Westinghouse men at every level of management, carefully selected to present an accurate cross section. The list of questions asked is shown in Table I. The results were compiled and analyzed and from the report several conclusions are apparent. In addition, some suggestions for report writers follow as a natural consequence.

What Management Looks for in Engineering Reports

When a manager reads a report, he looks for pertinent facts and competent opinions that will aid him in decision making. He wants to know right away whether he should read the report, route it, or skip it.

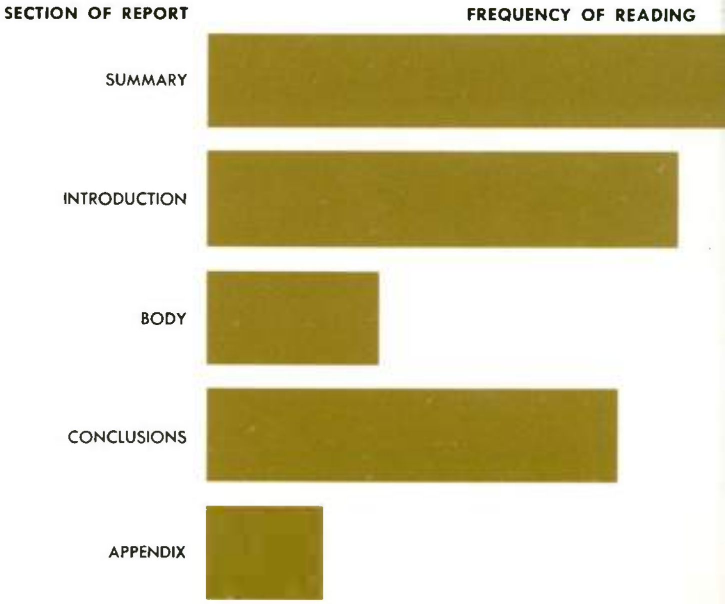
To determine this, he wants answers fast to some or all of the following questions:

This article was staff-written by Richard W. Dodge, based on information provided by a study made at Westinghouse in 1959–60 by Professor James W. Souther, Assistant Dean, College of Engineering, University of Washington.

Table I Questions Asked of Managers

1. What types of reports are submitted to you?
2. What do you look for *first* in the reports submitted to you?
3. What do you want from these reports?
4. To what depth do you want to follow any one particular idea?
5. At what level (how technical and how detailed) should the various reports be written?
6. What do you want emphasized in the reports submitted to you? (Facts, interpretations, recommendations, implications, etc.)
7. What types of decisions are you called upon to make or to participate in?
8. What type of information do you need in order to make these decisions?
9. What types of information do you receive that you don't want?
10. What types of information do you want but not receive?
11. How much of a typical or average report you receive is useful?
12. What types of reports do you write?
13. What do you think your boss wants in the reports you send him?
14. What percentage of the reports you receive do you think desirable or useful? (In kind or frequency.)
15. What percentage of the reports you write do you think desirable or useful? (In kind or frequency.)
16. What particular weaknesses have you found in reports?

Fig. 1 How Managers Read Reports



What's the report about and who wrote it?
What does it contribute?
What are the conclusions and recommendations?
What are their importance and significance?
What's the implication to the Company?
What actions are suggested? Short range? Long range?
Why? By whom? When? How?

The manager wants this information in brief, concise, and meaningful terms. He wants it at the beginning of the report and all in one piece.

For example, if a summary is to convey information efficiently, it should contain three kinds of facts:

1. What the report is about;
2. The significance and implications of the work; and
3. The action called for.

To give an intelligent idea of what the report is about, first of all the problem must be defined, then the objectives of the project set forth. Next, the reasons for doing the work must be given. Following this should come the conclusions. And finally, the recommendations.

Such summaries are informative and useful, and should be placed at the beginning of the report.

The kind of information a manager wants in a report is determined by his management responsibilities, but how he wants this information presented is determined largely by his reading habits. This study indicates that management report reading habits are surprisingly similar. Every manager interviewed said he read the *summary* or abstract; a bare majority said they read the *introduction* and *background* sections as well as the *conclusions* and *recommendations;* only a few managers read the *body* of the report or the *appendix* material.

The managers who read the *background* section, or the conclusions and recommendations, said they did so "... to gain a better perspective of the material being reported and to find an answer to the all-important question: What do we do next?" Those who read the *body* of the report gave one of the following reasons:

1. Especially interested in subject;
2. Deeply involved in the project;
3. Urgency of problem requires it;
4. Skeptical of conclusions drawn.

And those few managers who read the *appendix* material did so to evaluate further the work being reported. To the report writer, this can mean but one thing: If a report is to convey useful information efficiently, the structure must fit the manager's reading habits.

The frequency of reading chart in Fig. 1 suggests how a report should be structured if it is to be useful to management readers.

Subject Matter Interest

In addition to what facts a manager looks for in a report and how he reads reports, the study indicated that he is interested in five broad technological areas. These are:

1. Technical problems;
2. New projects and products;
3. Experiments and tests;
4. Materials and processes;
5. Field troubles.

Managers want to know a number of things about each of these areas. These are listed in Table II. Each of the sets of questions can serve as an effective check list for report writers.

In addition to these subjects, a manager must also consider market factors and organization problems. Although these are not the primary concern of the engineer, he should

Table II What Managers Want to Know

Problems
What is it?
Why undertaken?
Magnitude and importance?
What is being done? By whom?
Approaches used?
Thorough and complete?
Suggested solution? Best? Consider others?
What now?
Who does it?
Time factors?

New Projects and Products
Potential?
Risks?
Scope of application?
Commercial implications?
Competition?
Importance to Company?
More work to be done? Any problems?
Required manpower, facilities and equipment?
Relative importance to other projects or products?
Life of project or product line?
Effect on Westinghouse technical position?
Priorities required?
Proposed schedule?
Target date?

Tests and Experiments
What tested or investigated?
Why? How?
What did it show?
Better ways?
Conclusions? Recommendations?
Implications to Company?

Materials and Processes
Properties, characteristics, capabilities? Limitations?
Use requirements and environment?
Areas and scope of application?
Cost factors?
Availability and sources?
What else will do it?
Problems in using?
Significance of application to Company?

Field Troubles and Special Design Problems
Specific equipment involved?
What trouble developed? Any trouble history?
How much involved?
Responsibility? Others? Westinghouse?
What is needed?
Special requirements and environment?
Who does it? Time factors?
Most practical solution? Recommended action?
Suggested product design changes?

The Four Steps in Supervising Report Writing

1. **Agreement on Objectives**

2. **Discussion of Results**

furnish information to management whenever technical aspects provide special evidence or insight into the problem being considered. For example, here are some of the questions about marketing matters a manager will want answered:

What are the chances for success?
What are the possible rewards? Monetary? Technological?
What are the possible risks? Monetary? Technological?
Can we be competitive? Price? Delivery?
Is there a market? Must one be developed?
When will the product be available?

And, here are some of the questions about organization problems a manager must have answered before he can make a decision:

Is it the type of work Westinghouse should do?
What changes will be required? Organization? Manpower? Facilities? Equipment?
Is it an expanding or contracting program?
What suffers if we concentrate on this?

These are the kinds of questions Westinghouse management wants answered about projects in these five broad technological areas. The report writer should answer them whenever possible.

Level of Presentation

Trite as it may sound, the technical and detail level at which a report should be written depends upon the reader and his use of the material. Most readers—certainly this is true for management readers—are interested in the significant material and in the general concepts that grow out of detail. Consequently, there is seldom real justification for a highly technical and detailed presentation.

Usually the management reader has an educational and experience background different from that of the writer. *Never* does the management reader have the same knowledge of and familiarity with the specific problem being reported that the writer has. *Therefore, the writer of a report for management should write at a technical level suitable for a reader whose educational and experience background is in a field different from his own.* For example, if the report writer is an electrical engineer, he should write his reports for a person educated and trained in a field such as chemical engineering, or mechanical engineering, or metallurgical engineering.

All parts of the report *should preferably* be written on this basis. The highly technical, mathematical, and detailed material—if necessary at all—can and should be placed in the appendix.

Management Responsibilities

The information presented thus far is primarily of interest to the report writer. In addition, however, management itself has definite responsibilities in the reporting process. These can be summed up as follows:

1. Define the project and the required reports;
2. Provide proper perspective for the project and the required reporting;
3. See that effective reports are submitted on time; and
4. See that the reports are properly distributed.

An engineering report, like any engineered product, has to be designed to fill a particular need and to achieve a particular purpose within a specific situation. Making sure that the writer knows what his report is to do, how it is to be used, and who is going to use it—all these things are the responsibilities of management. Purpose, use, and reader are the design factors in communications, and unless the writer knows these things, he is in no position to design an effective instrument of communication—be it a report, a memorandum, or what have you.

Four conferences at selected times can help a manager control the writing of those he supervises and will help him get the kind of reports he wants, when he wants them.

Step 1—At the beginning of the project. The purpose of this conference is to define the project, make sure the engineer involved knows what it is he's supposed to do, and specify the required reporting that is going to be expected of him as the project continues. What kind of decisions, for example, hinge upon his report? What is the relation of his work to the decision making process of management? These are the kinds of questions to clear up at this conference.

If the project is an involved one that could easily be misunderstood,

3. Discussion of Outline

4. Review and Distribution

the manager may want to check the effectiveness of the conference by asking the engineer to write a memorandum stating in his own words his understanding of the project, how he plans to handle it, and the reporting requirements. This can assure a mutual understanding of the project from the very outset.

Step 2—At the completion of the investigation. When the engineer has finished the project assignment—but before he has reported on it—the manager should have him come in and talk over the results of his work. What did he find out? What conclusions has he reached? What is the main supporting evidence for these conclusions? What recommendations does he make? Should any future action be suggested? What is the value of the work to the Company?

The broader perspective of the manager, plus his extensive knowledge of the Company and its activities, puts him in the position of being able to give the engineer a much better picture of the value and implications of the project.

The mechanism for getting into the report the kind of information needed for decision making is a relatively simple one. As the manager goes over the material with the engineer, he picks out points that need to be emphasized, and those that can be left out. This is a formative process that aids the engineer in the selection of material and evidence to support his material.

Knowing in advance that he has a review session with his supervisor, the chances are the engineer will do some thinking beforehand about the project and the results. Consequently, he will have formed some opinions about the significance of the work, and will, therefore, make a more coherent and intelligent presentation of the project and the results of his investigation.

This review will do something for the manager, too. The material will give him an insight into the value of the work that will enable him to converse intelligently and convincingly about the project to others. Such a preview may, therefore, expedite decisions influencing the project in one way or another.

Step 3—After the report is outlined. The manager should schedule a third conference after the report is outlined. At this session, the manager and the author should review the report outline step-by-step. If the manager is satisfied with the outline, he should tell the author so and tell him to proceed with the report.

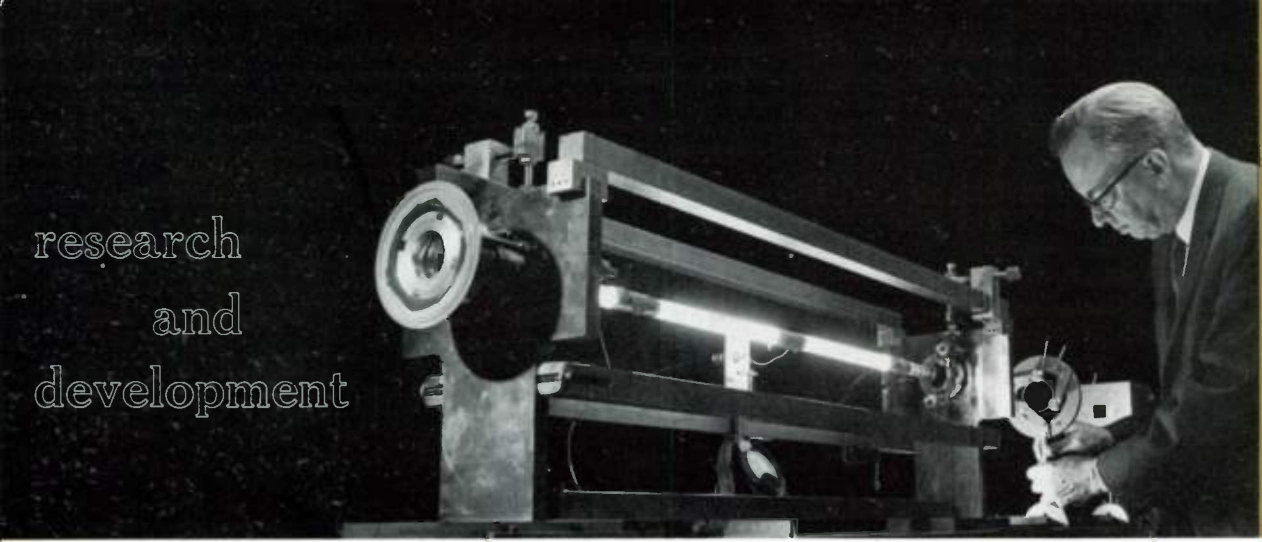
If, however, the manager is not satisfied with the outline and believes it will have to be reorganized before the kind of report wanted can be written, he must make this fact known to the author. One way he can do this is to have the author tell him why the outline is structured the way it is. This usually discloses the organizational weakness to the author and consequently he will be the one to suggest a change. This, of course, is the ideal situation. However, if the indirect approach doesn't work, the more direct approach must be used.

Regardless of the method used to develop a satisfactory outline, the thing the manager must keep in mind is this: It's much easier to win the author's consent to structural changes at the outline stage, i.e., *before* the report is written, than afterward. Writing is a personal thing; therefore, when changes are suggested in organization or approach, these are all too frequently considered personal attacks and strained relations result.

Step 4—After the report is written. The fourth interview calls for a review and approval by the manager of the finished report and the preparation of a distribution list. During this review, the manager may find some sections of the report that need changing. While this is to be expected, he should limit the extent of these changes. The true test of any piece of writing is the clarity of the statement. If it's clear and does the job, the manager should leave it alone.

This four-step conference mechanism will save the manager valuable time, and, it will save the engineer valuable time. Also, it will insure meaningful and useful project reports—not an insignificant accomplishment itself. In addition, the process is an educative one. It places in the manager's hands another tool he can use to develop and broaden the viewpoint of the engineer. By eliminating misunderstanding and wasted effort, the review process creates a more helpful and effective working atmosphere. It acknowledges the professional status of the engineer and recognizes his importance as a member of the engineering department.

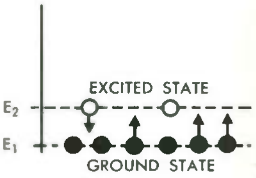
research and development



Experimental helium-neon gas laser for studying the application of lasers to military communications and ranging.

1

If an electromagnetic field of frequency $v = (E_2 - E_1)/h$ is applied, there will be an equal probability of each ground state atom (E_1) absorbing energy and becoming excited, and each excited atom (E_2) radiating energy and dropping to ground state.



COHERENT LIGHT . . . A New Tool for Science

Although man has been using visible light for a longer time than any other portion of the electromagnetic spectrum, he has only recently developed a device for generating *coherent light*—light waves of a single frequency that vary in a regular sinusoidal pattern, similar to radio waves. The generating device, popularly known as a *laser* (acronym for *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation) was first successfully demonstrated in 1960 (T. H. Maiman, Hughes, August 1960). The emission from a laser is characterized by narrow spectral width, high directionality, and very high intensities.

Several experimental lasers of various types are in operation, but much development is needed before the device can assume significant practical value. However, if man can achieve the control over light that he now commands over the radio frequency spectrum, whole new fields of science will be opened. Light from most sources is an irregular and unpredictable electromagnetic field of many frequencies. If this energy can be obtained in large amounts as a single-frequency, sinusoidal field, science will have an energy source capable of almost miraculous accomplishment.

Stimulated Emission

Light is generated when an electron in a high energy state (traveling in an orbit far removed from the nucleus of an atom) falls to a lower energy state (an orbit closer to the nucleus), giving off energy in the form of electromagnetic radiation. Conversely, light is absorbed when an electron takes energy from an electromagnetic field and moves to a higher energy orbit.

By the rules of quantum theory, electrons can occupy only certain energy levels in an atom or molecule; therefore, energy transfers between electrons and an electromagnetic field are limited to certain definite quanta or increments of energy. According to the Planck Law, the fundamental law of the quantum theory, electromagnetic energy is a function of frequency, as expressed by the formula,

$$E = hv,$$

where E is the quantum of energy, v is the frequency of radiation, and h is the constant of proportionality known as *Planck's constant*. (The quantum of light energy, E, is commonly known as a *photon*.) Therefore, the energy difference between any two energy levels in an atom can be expressed as:

$$E_1 - E_2 = hv$$

where E_1 and E_2 are the permitted energy levels. Since frequency is the only variable, energy transfer between levels is possible only for certain frequencies.

Most light—such as that from a fluorescent lamp—is generated in a random or noncoherent fashion. With the laser, science has found a method for synchronizing this random radiation. The active atoms must be chosen and excited in such a way that they will release radiation in phase and at a single frequency.

Consider a material that contains atoms at two energy levels, E_1 and E_2 (Fig. 1). If an electromagnetic field is applied at the proper frequency to satisfy Planck's Law, it would excite some of the atoms in E_1, and raise them to E_2 (these atoms would absorb light); conversely, there would be an equal probability of excited atoms in E_2 releasing energy to the field and dropping back to E_1 (these atoms would generate light). In the situation shown in Fig. 1, since there are more atoms at E_1 than E_2, more atoms would absorb radiation than release radiation. To obtain a net gain in electromagnetic radiation, it is necessary to reverse this condition by getting more atoms into E_2 than E_1. This condition is known as ***population inversion***.

Population inversion can be accomplished by use of a third energy level, E_3 (Fig. 2). Preferably, E_3 is a band of closely spaced energy levels slightly above E_2. When an atom is "pumped" from E_1 to E_3, it will stay there only a matter of hundredths of a microsecond and then drop back to E_2, giving up its excess energy, usually in the form of heat. If the material is pumped sufficiently so that there are more atoms at level E_2 than E_1, an electromagnetic field of the proper frequency will then cause more atoms to release energy than absorb energy, producing light emission. The important characteristic of emission stimulated in this fashion is that the light produced will have the same frequency and phase, and travel in the same direction as the stimulating field.

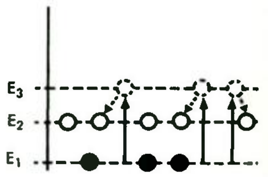
The difficulty with the type of laser operation just described, commonly called *ground state* operation, is that a large amount of pumping energy is required to achieve population inversion. Therefore, the more sophisticated versions of lasers employ what is called *excited state* operation. Here, the active atoms have an additional energy level and all but the ground state are virtually empty. In the example shown in Fig. 3, atoms are pumped to the energy absorption band E_4, from which they drop back to E_3 with a release of heat. Since there are few atoms at energy level E_2, population inversion between levels E_3 and E_2 is accomplished with a minimum of pumping energy.

Laser Operation

The generation of coherent light is demonstrated by the ruby optical maser, shown symbolically in Fig. 4. The ruby rod is an aluminum-oxide (Al_2O_3) crystal with about 0.05 percent concentration of chromium impurity atoms. The active

2

By employing atoms with an absorption energy level E_3 and applying an electromagnetic field of frequency $v=(E_3-E_1)/h$, ground state atoms are pumped to E_3, and immediately drop back to E_2 to produce population inversion over E_1 level.



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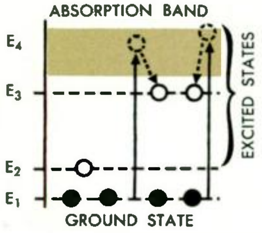
Excited-state operation is accomplished with a minimum of pumping energy requirements. Ground state atoms are pumped to the energy absorption band E_4, drop back to E_3 level, and thereby produce a population inversion over the virtually empty E_2 level.



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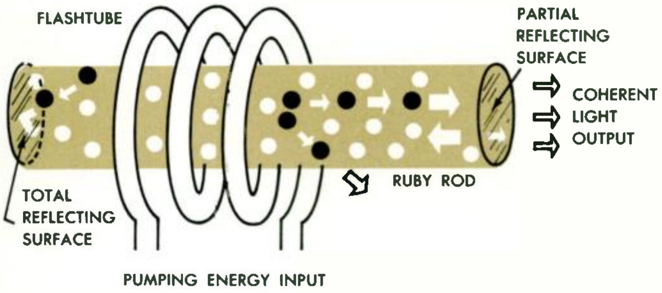
This schematic drawing of a ruby laser illustrates the generation of coherent light. Optical pumping energy from the helical flash tube excites chromium atoms (white dots) in the ruby rod; a few of these excited atoms spontaneously drop back, releasing electromagnetic radiation which causes others to radiate (black dots). Radiation parallel to rod is reflected by silvered ends and amplified.



chromium atoms are excited by the optical energy from the encircling flashtube, producing a population inversion. A few excited atoms spontaneously fall back, emitting radiation; this radiation induces other excited atoms to release energy, of the same phase and frequency. Both ends of the ruby rod are silvered, with one end slightly transparent. Electromagnetic energy of the proper phase and parallel to the axis of the rod is reflected between the mirrors and further amplified; the semitransparent mirror at one end allows a part of this generated light to emerge in the form of a coherent, highly directional beam.

Solid State And Liquid Lasers

The theory of solid state and liquid laser operation is fairly similar, although a successful liquid laser has yet to be reported in the literature.

Solid laser material is composed of active atoms held in a host lattice. Designers must consider both factors in developing laser materials.

Three types of elements can be considered for the active atoms: (1) *transition metals*, the elements with an incomplete inner shell; (2) the *lanthanides*, or rare earth elements of atomic number 57 through 71; (3) the *actinides*, elements of atomic number 89 through 103.

In each of these elements the active electrons are in the inner shells and so are relatively well shielded from the surrounding environment. These elements have narrow emission lines and, with some exceptions in the lanthanides, broad absorption bands. (The broad absorption bands are due to the absorption energy states being in outer electron shells that are less well shielded.)

In the choice of a host lattice, the ground rules are not yet well understood. Ideally, the host crystal should be as perfect as possible, with only a few interspersed active atoms, so that the active atoms are well buffered from each other. The host should make possible a high efficiency of conversion from broad band absorption to narrow line emission. In studies of the influence of the host element on the energy levels of the active atom, the host has been found to determine the permitted energy levels of the active atom. Hence, for the same active atom, some transitions will be observed in one host, not in another; or, the quantum efficiency for the same transition may vary from one host to another. Hence, the host material will determine the operating frequency of the laser. Research is currently being carried on at the Westinghouse Research Laboratories to determine the influence of host lattice parameters on the quantum efficiency. Westinghouse scientists are also investigating methods for sensitizing laser materials to obtain increased spectral width for the absorption of exciting energy. Sensitization mechanisms being considered include host lattice sensitization, sensitization with other ionic species, transfer processes between the host molecule and the emitting ion, and resonant transfer processes between molecular species.

Gas Lasers

The operation of a gas laser, and hence the desired characteristics of the gas, are considerably different from solid lasers. A major difference is that in gases, the absorption bands are extremely narrow, so that optical excitation of the form used for solid lasers is not attractive. Therefore, scientists are investigating other schemes for pumping gas lasers.

One method is *collision excitation*, the method used in the helium-neon laser. One gas in the mixture is excited with radio-frequency energy, and the excitation energy is transferred from this gas to the active constituent by collision. In the case of the He-Ne laser, helium is excited by rf energy and transfers its energy in turn to neon.

A second method is *molecular dissociation*. For example, the absorption band for dissociating the rubidium-iodine molecule by optical energy is broad; once dissociated, the rubidium atom is left in an excited state.

Both of the above methods make the pumping of the gas laser considerably easier than for solid lasers.

Applications For Coherent Light

Scientists and engineers can envision many potential applications for the laser, from Buck Rogers' forms of disintegrating ray guns to extremely high capacity carrier beams for space communication.

For example, the helium-neon gas laser which was put into operation in May 1961 at the Westinghouse Electronics Division, has a beam of divergence of only 20 seconds of arc. With this small beam divergence, a 0.1 mil diameter source aimed at the moon would produce a spot size on the moon only 20 miles in diameter.

Extremely high energy concentrations can be achieved with a coherent light beam. Already, scientists have obtained values of the order of 10^9 watts/cm^2. (Sunlight provides only 0.1 watt/cm^2 over the entire visible spectrum.) Such high energy concentrations would make the laser ideally suited for precision welding or burning applications. It also appears possible that some chemical reactions may be made to take place in this high concentration of energy.

Many other potential applications of the laser seem possible; but a number of problems have yet to be solved. Much must be learned about laser materials, so that greater power levels can be achieved, and a wider range of coherent frequencies can be generated. The efficiency of coherent light generation must be improved. And techniques must be developed for effectively controlling and modulating coherent light.

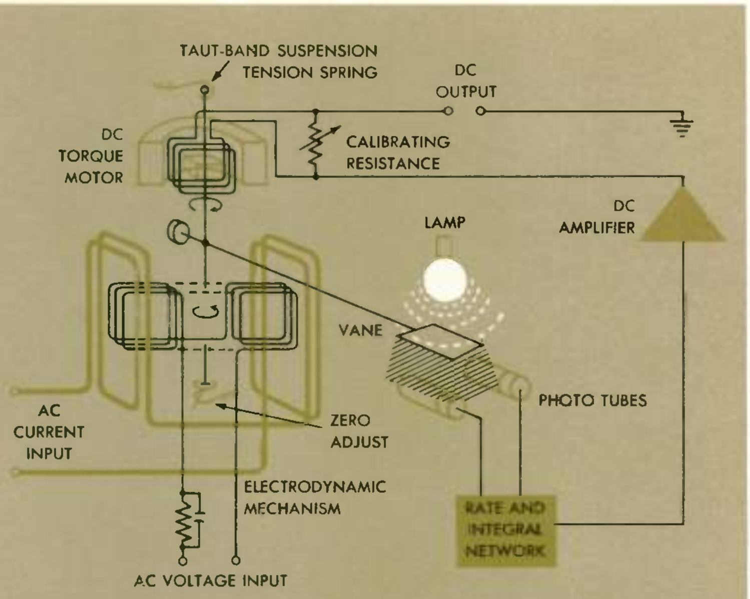


Fig. 1 Functional diagram of torque-balance watt transducer.

A High-Accuracy Torque-Balance Transducer

B. E. Lenehan
J. T. Wintermute
Relay-Instrument Division
Westinghouse Electric Corporation
Newark, New Jersey

The torque-balance transducer is a servo-mechanism device whose dc output can be made proportional to ac watts, or to the product of two dc currents; in another design, the output can be made proportional to the rms value of current or voltage. The transducer is particularly applicable where high-accuracy measurements of low-energy or low-power-factor signals are required. The instrument was originally developed for two applications: measurement of corona watt loss on high-voltage transmission lines, and measurement of transformer core losses and form-factor of the transformer voltage (by measuring rms and average voltages) on a production-line basis. In another application, the transducer is being used to determine bearing wear on gyroscope motors. The transducer is sufficiently sensitive so that wear can be determined by measuring the change in power input to the motor.

Torque-Balance Principle

The principle of operation of the torque balance transducer is not new. Precision wattmeters have for many years used a torque-balance mechanism, in which the physical relationship between the movable element and the stationary coils is held constant by varying balancing torque with a calibrated torsion head. Since the relative position of the coils is fixed, the coefficient of mutual inductance does not vary as in the deflection type of instrument. However, this torsion type of instrument has two fundamental drawbacks for industrial application: it is inconvenient to read, and it cannot furnish an output signal. Both of these handicaps have been eliminated in the Type 843 transducer. This device consists of an electrodynamic torque-producing mechanism and a dc balancing element, both mounted on the same shaft, which is suspended between taut bands. When the electrodynamic element is energized, a deflection from the balance position produces an error signal in a photoelectric detecting system, which in turn causes a current to flow in the dc balancing element to develop opposing torque to the electrodynamic element. The magnitude and direction of the balancing direct current

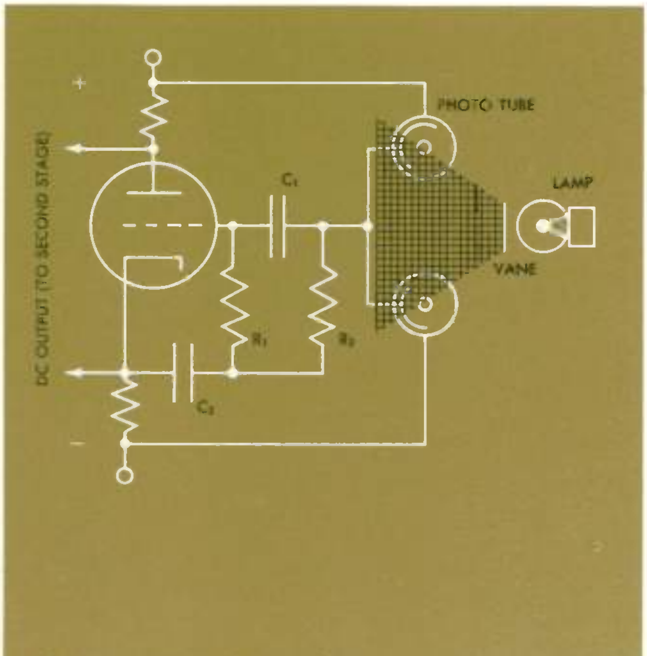


Fig. 2 Photo tube error-detector system and transfer-impedance network.

Complete watt-transducer chassis, removed from its case.

required is proportional to the power flow in the measured circuit. This dc signal can be used to operate read out instruments, recorders, or telemetering transmitters.

Watt-Transducer Operation

The complete watt transducer is shown schematically in Fig. 1. It is basically a single-phase wattmeter, which produces a dc output signal proportional to watt input.

The electrodynamic input mechanism consists of two stationary coils and two moving coils, paired to form two torque-producing units. The two electrodynamic units are astatically connected (wound in opposite directions), so that any uniform stray field will produce cancelling counter torques in the two units. Current and voltage inputs produce additive torques.

Error Detector Operation—Light input to the two vacuum-type photo tubes is controlled by the moving vane, which during balance permits half of each tube to be illuminated.

The photo tubes are connected in series across a dc voltage, with their midpoint connected to a high-impedance transfer network (R_1, C_1, R_2, C_2, Fig. 2). Under steady-state conditions, capacitor C_2 is fully charged and no current flows through the shunt circuit across the grid-cathode; the sensitivity of the error detector in this condition is extremely high, providing practically infinite resolution.

During a transient condition (when the vane is moving) the light received by one photocell is decreasing and the other is increasing, the two photocells acting like a single current source. The changing current through R_2 produces a changing voltage across C_1 and a voltage across R_1 proportional to the velocity of the vane; this voltage disappears when the vane stops. At the same time, the current is flowing into C_2, charging it to the voltage needed by the changed condition. Resistances R_1 and R_2 have values of several megohms, so that a large voltage change can occur across the grid-cathode to restore the system to balance. The transfer network effectively provides this large corrective voltage for transients to obtain quick balance; a more slowly changing voltage is provided as steady state is approached to obtain high resolution.

Calibration is unaffected by a change in gain of the amplifier. The calibration-determining units are the electrodynamometer torque-producing mechanism and the dc counter-torque-producing mechanism. Calibration adjustment is accomplished with a variable resistance which shunts the dc torque mechanism.

Vacuum-type photo tubes were selected because of their stability; any change in characteristics usually occurs in both tubes. However, if the photo tubes change their characteristics independently, only a zero shift occurs. To set the transducer on zero, a mechanical zero adjuster is provided to adjust the position of the taut-band suspension.

Temperature effects are cancelled out by the transducer because temperature-produced current changes in the ac and dc mechanisms are made equal, and produce equal changes in the opposing torques.

Low Power Factor Performance

The usual deflection-type wattmeter cannot provide sufficient in-phase ampere turns for operation at normal torque levels for power factors less than about 10 percent. In the watt transducer, the error-detector and amplifier provide a *variable* restoring torque; furthermore, since the moving element operates over a very small angle, closer coupling between the stationary and moving coils is achieved. As a result, the sensitive device is suited to power measurement at power factors down to 0.5 percent, where normal wattmeter movements cannot function accurately. Phase angle compensation in the potential circuit is provided to permit operation at these low power factors. The compensation consists of a capacitor shunted across part of the potential-circuit multiplier resistance, to compensate for the potential coil inductance.

Watt Transducer Ratings

A standard watt transducer is rated at 2.5/5 amperes, 100–200 volts input, 20 milliamperes dc output, accuracy ±0.1 percent. However, transducers have been made for inputs as low as 3 watts, 24 volts, with a maximum current rating of 2 amperes. The output load resistance may be any value up to 2000 ohms. Since iron-cored inductances are not used in any part of the signal circuit, frequency range can be from very low frequencies up to several thousand cycles per second.

For maximum accuracy, the readout instrument should be a precision potentiometer used in conjunction with a precision shunt, although any device requiring a dc input can be used. If the application requires, a filter may be placed in the output current circuit to eliminate some ripple which is present from the amplifier power supply.

Multiple current ranges other than those obtained by series-parallel connection of the two stationary coils can be achieved by winding the stationary coils with individually stranded cable, which can be grouped in various series-parallel connections and the junction leads brought out to provide the different ranges. For example, a 1/2.5/10 amperes instrument has been made in this manner with a 17-strand cable, eliminating the need for current transformers with their possible phase-angle error.

The transducer chassis is mounted in a dustproof case, with knife-blade connectors, which permits the chassis to be removed from the case or to be disconnected while in the case without open-circuiting the current circuits.

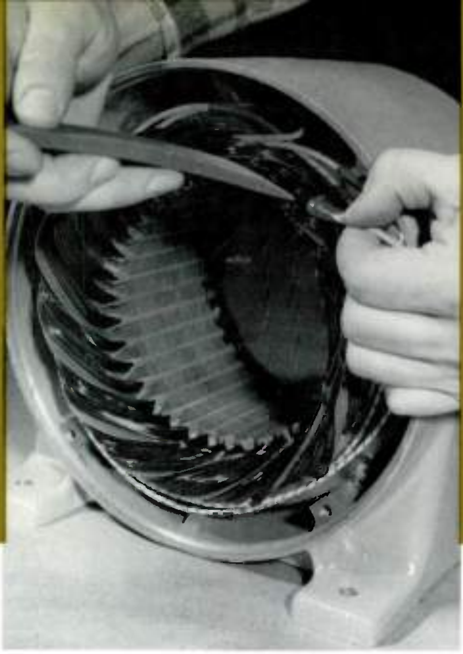
Other Applications

The same principle of torque-balance operation, with taut-band suspension and the photoelectric error-sensing unit, is applied to the rms transducers, which have a dc output proportional to the true rms value of an alternating current or voltage. In these transducers, the permanent magnet dc torque motor is replaced by an electrodynamometer mechanism to supply the balance torque. The balance torque produced is therefore proportional to the square of the dc current, equal and opposite to the torque produced by the measuring electrodynamometer, thus providing linear dc output versus rms input.

The application of the taut-band suspension system, which was originally developed for switchboard instruments, to precision watt-transducers and true rms transducers of the torque-balance servo-type has resulted in a rugged precision instrument. Taut-band suspension makes possible a movement with unlimited resolution—no "deadband" areas—because of the absence of pivot friction.

Solid-state thermistors embedded in windings protect ac motors against burnouts and prevent nuisance trips. They provide inverse time-temperature protection instead of the inverse time-current protection afforded by thermal overload relays.

John J. Courtin
Motor and Gearing Division
Westinghouse Electric Corporation
Buffalo, New York



Left PTC thermistors wired in series are embedded in the winding of a Guardistor motor. An overtemperature signal from them shuts down the motor or alerts the operator.

Below A control relay and three thermistors are the protective components of a typical three-phase Guardistor motor.

Applying the Guardistor Motor Protection System

Integral-horsepower ac motors have long been protected from overheating by devices sensitive to line currents (usually thermal overload relays) that attempt to duplicate within themselves the heating characteristics of the motor. Line current does have a proportionality to the temperature of a motor's winding, but it is not a true indication of temperature.[1] Therefore, even though thermal overload relays are constantly being improved, motor users still encounter frequent burnouts or nuisance trips when the devices are applied with three-phase induction motors on duty cycles, on fluctuating loads, for accelerating high-inertia drives, where currents oscillate (compressors, oil-well pumps, flywheels), and on power lines having unbalanced voltages. Burnouts occur also when the motor stalls, one phase is lost from the power source, intermittent motors run overtime, or ventilation is blocked.

Both burnouts and nuisance trips are prevented in the Guardistor motor because protection is based directly on the temperature of the winding itself. This temperature is sensed by reliable solid-state thermistors. To prevent a winding from burning out, the system merely shuts off the power or signals the operator before a damaging temperature is reached. To eliminate nuisance trips, the system allows the motor to work to its full capability within the limiting temperature of its insulation class.

Development

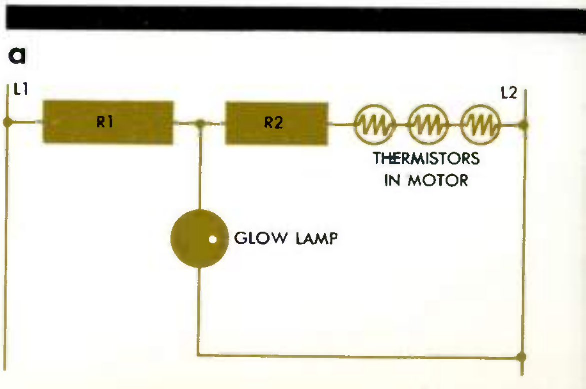
Fractional-horsepower motors and small integral-horsepower motors (to five horsepower) have been successfully protected with bimetal thermal protectors containing heaters that carry line current and are located on or near the motor windings. However, since these thermal protectors must carry and interrupt line current, their application is limited to the small machines. Ordinary air-filled thermostats do not respond quickly enough to protect an ac stator winding for a locked rotor condition even when embedded in it.

Thus, a new device was needed to extend the advantages of inherent thermal protection to larger machines. Since startup vibration increases with motor size, a solid-state device was indicated.

The answer was the Westinghouse positive-temperature-coefficient (PTC) thermistor, an aspirin-size semiconductor device. Because its resistance increases with temperature, the PTC thermistor has an inherent safety feature—an opening in its connections has the same effect as an unsafe temperature. Also, the small size makes it possible to install PTC thermistors in intimate contact with the stator windings and thus minimize thermal lag between their temperature and the winding temperature. Standard induction motors up to 200 hp can be protected for all conditions of overload (including stalled rotor) by limiting the temperature of the stator winding insulation.

The PTC thermistor has a positive switching action that makes it suitable for direct connection in simple control circuits. Its resistance is low at normal temperatures and remains nearly constant up to a critical temperature. Then a slight increase in temperature multiplies its resistance several hundred times. Five ratings fit the thermistors to any motor insulation class.

The protective equipment for a three-phase Guardistor



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[1] "Temperature Protection for Induction Motors," by J. K. Howell and J. J. Courtin, *Westinghouse ENGINEER*, Vol. 19, No. 6, Nov. 1959, p. 182.

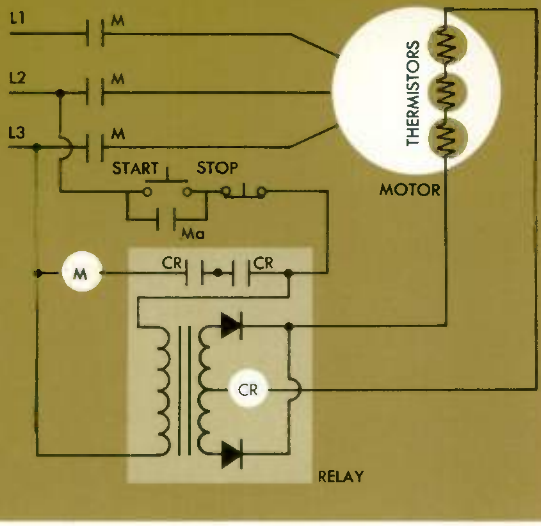


Fig. 1 (Right) Resistance rise in the motor thermistors of this typical circuit causes relay contacts *CR* to open. This opens power contacts *M* to shut down the motor.

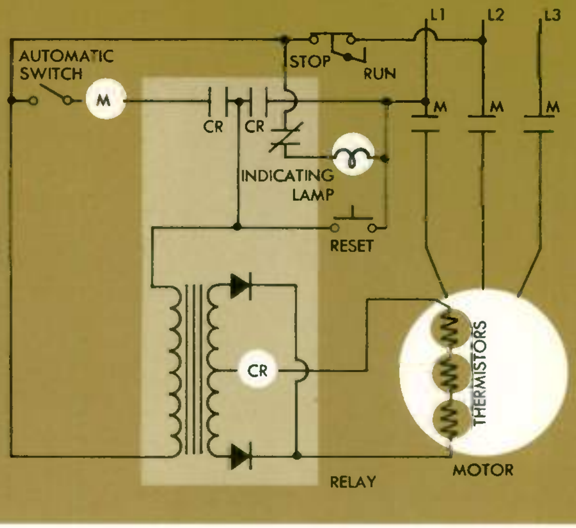


Fig. 2 (Far Right) The Guardistor motor is operated here by a thermostat or other automatic switch. An overtemperature shuts off the motor and lights an indicating lamp. Pressing the *reset* button restarts the motor.

motor consists of a harness of three thermistors in series and, usually, a control relay. The thermistors go into the upper end turn portion of the stator winding, inserted snugly with potting cement between coil strands in each of the three phases. Varnish impregnation and baking make the thermistors an integral mass with the winding.

Circuit Applications

A typical harness at normal operating temperatures has a resistance below 200 ohms, and the associated protection relay is set to operate if resistance reaches 1500 ohms. The stock Guardistor motor relay contains a control transformer, two silicon diodes, a control relay with two normally open and two normally closed contacts, and a terminal block. Many circuits are possible for translating the overtemperature signal into a shutdown or alarm function.

A Guardistor motor controlled by a standard pushbutton station with low-voltage protection is diagrammed in Fig. 1. Thirty volts dc is applied across the series connection of three thermistors and the relay coil *CR*. Normal current is 0.06 ampere, and the relay drops out at 0.016 ampere. Pressing the *start* button energizes the transformer and coil *CR*, closing contacts *CR*. Motor power contactor coil *M* is energized, closing power contacts *M* and hold-in contacts *Ma*. The motor runs until the *stop* button is pressed or until an increase in the thermistor resistance caused by overtemperature causes *CR* to drop out and shut down the motor. After an overtemperature trip, the winding must cool 15 degrees C lower than trip temperature before the *start* button will again pick up *CR* (it requires 0.030 ampere) and allow the motor to restart. On very low voltage or loss of voltage, contactor *M* drops out, contact *Ma* opens, and the motor does not restart on restoration of voltage until the *start* button is pressed.

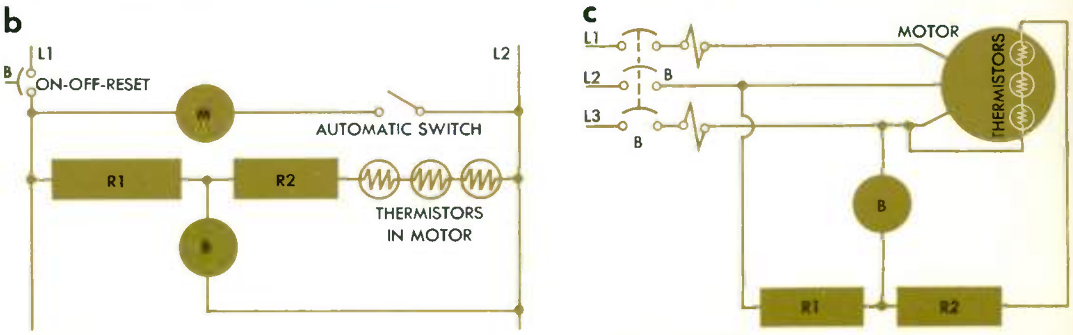
Replacing the pushbutton station with a maintained-contact switch provides a circuit in which the motor restarts automatically upon cooling after a shut-down.

A more complex control system is the arrangement for air-conditioning and pumping applications diagrammed in Fig. 2. Closing the maintained-contact switch and pressing the *reset* button picks up control relay *CR* and permits the motor to cycle on a thermostat or some other automatic switch. A thermistor resistance rise causes the relay to drop out, shutting off motor power, and the relay's normally closed contact lights the indicating lamp. The motor cannot restart until an operator presses the *reset* button.

Control leads to the thermistor harnesses can be any length needed, so the relay panel is often mounted in control centers. The normally closed relay contacts are frequently connected to energize shunt trip coils of circuit breakers. On process drives, where shutdown is not permitted, the normally closed contacts can actuate alarms.

The resistance rise of PTC thermistors can also be used to perform control functions directly. In Fig. 3a, the sum of two fixed resistances limits current through the motor thermistors below their rating. The ratio of resistances is such that glow-lamp voltage is below the firing level when the thermistors are at normal temperature. If the motor starts to overheat, the rise in thermistor resistance raises voltage across the lamp and lights it. This circuit is often used in process drives where an automatic shutdown would be undesirable. A lighted warning lamp tells the operator to reduce load on the motor or make an orderly shutdown of the process.

FIG. 3 The resistance rise of the Guardistor motor's thermistors can be used to perform control functions directly, as shown in these three examples. a) Resistance rise raises voltage across the signal lamp and lights it. b) The same effect trips a circuit breaker. c) Thermistor action trips the center pole of the connected circuit breakers to provide overtemperature protection for a small three-phase motor.



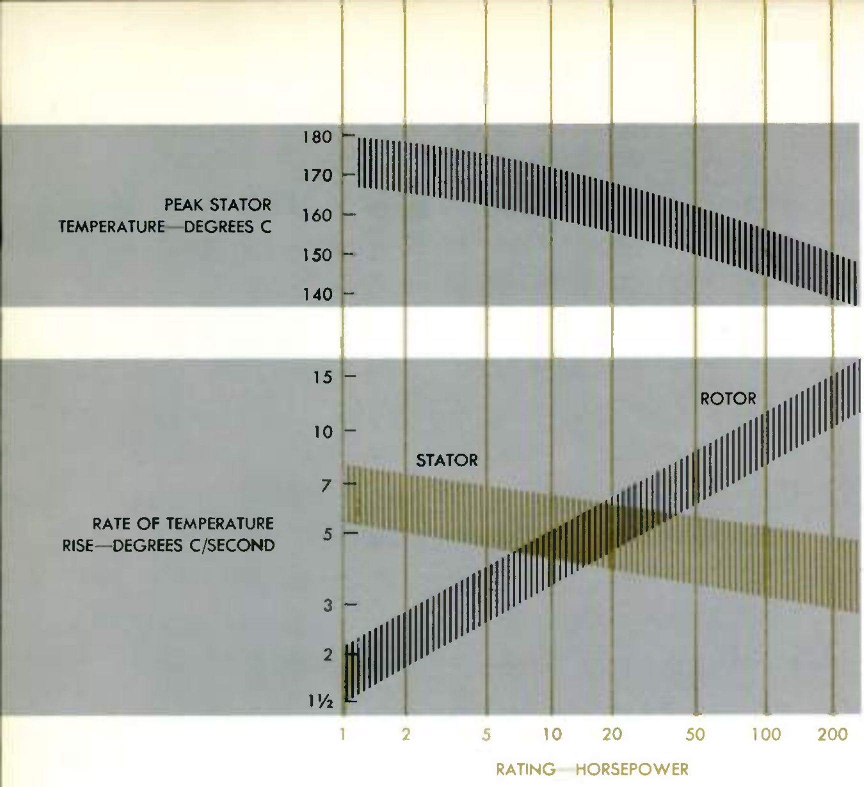


Fig. 4 Ranges of locked-rotor rate of temperature rise in some general-purpose Guardistor motors (Class A insulation) are shown in the lower bands. The upper band shows peak stator temperatures reached when the protection system interrupted the power. Values are for rated voltage, cold start, 40 degrees C ambient.

The same principle is used to trip a small panel-type magnetic circuit breaker (Fig. 3b). The breaker has relay trip construction in that coil leads and contact leads come out through individual studs, and it is an instantaneous-trip type for stalled-rotor protection. In the arrangement shown, the breaker is used for manual switching of the control circuit, and the motor normally cycles on the automatic switch. Current in breaker coil *B* is set at 50 percent of its trip value by the resistors at normal running temperatures. Resistance increase in the thermistors raises the coil voltage, and contact *B* opens to de-energize the motor.

This circuit is simpler than the ones that use the relay panel, and the breaker handle announces an overtemperature trip by its position. However, protection is lost if low voltage—say under 70 percent of nominal—occurs and conditions are such that motor contactor *M* stays closed and breaker coil *B* does not get enough voltage to trip.

Three breakers with a common trip bar can serve as manual control for a small three-phase Guardistor motor (Fig. 3c). The center pole has instantaneous-trip relay construction to provide overtemperature protection by thermistor action. The other two poles have series-trip coils with time delay to provide circuit fault protection.

With or without the relay, all switching is done outside the motor enclosure. Any contact problems are easily corrected in the control cabinet.

Temperature Considerations

Motor designers agree that temperature rises of 25 to 50 degrees C above hot-spot values are allowable in stator windings during acceleration. After all, coil baking temperatures are of this order, so brief excursions into this region have negligible effect on insulation life.

PTC thermistors have thermal lag, so on a full-voltage stall the winding temperature overshoots the thermistor temperature rating. The amount of overshoot generally is 25 to 50 degrees C. This overshoot is desirable because it allows the motor to accelerate its load without a nuisance trip and to sustain other momentary high overloads.

On running overloads there is no overshoot, so the thermistors protect the winding at the value of their continuous limiting temperature. They never operate below their continuous rating.

Thermal lag in a temperature-sensing element is proportional both to the mass of the element and to the rate of temperature rise. The mass of Guardistor motor thermistors is kept small enough so that windings cannot reach a damaging temperature. Locked-rotor rate of rise in induction motor stator windings is directly proportional to the current density in the coils, which is readily determined.

Typical ranges of locked-rotor rates of temperature rise for stators and rotors of general-purpose Guardistor motors are shown in Fig. 4. The rate of rise for stators generally decreases as motor size increases, whereas the rotor rate of rise increases as size increases. For this reason, large motors (above 200 horsepower) cannot be fully protected against stalled rotor by sensing stator winding temperature.

Peak temperatures reached when the protection system interrupted the power are plotted at the top in Fig. 4. Even in the emergency condition (cold motor, full voltage, locked rotor) power is interrupted before temperatures reach damaging levels, so the protection is adequate.

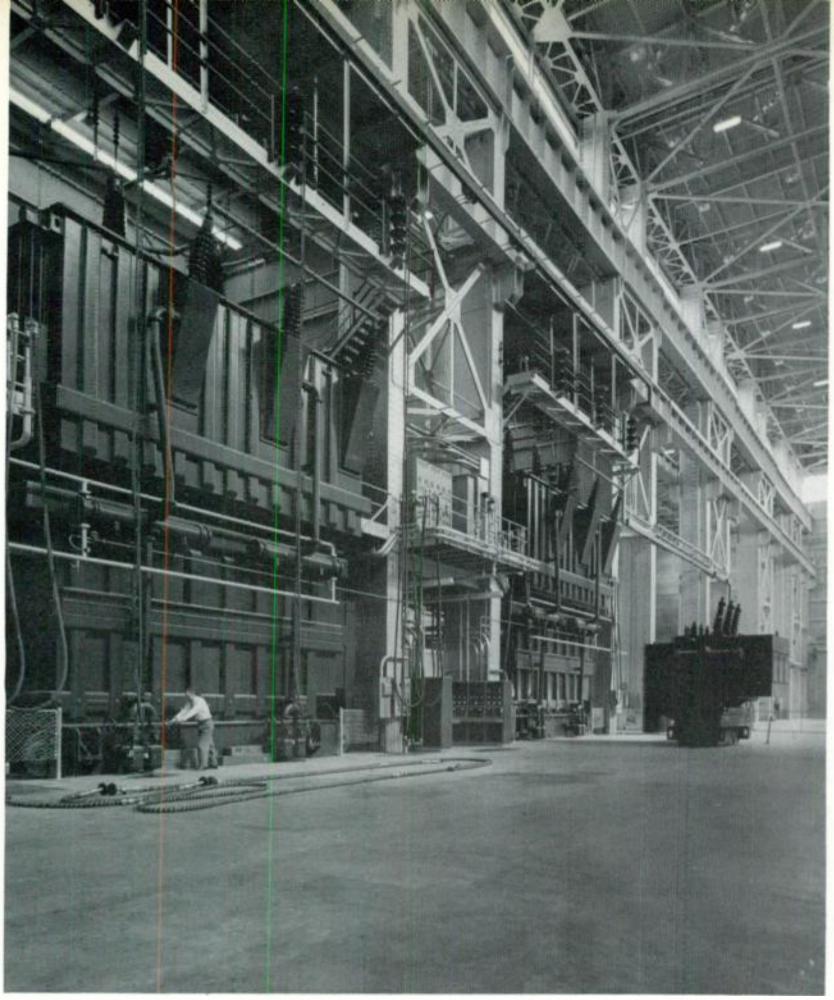
If the winding is warm when a stall occurs, peak temperature and trip time are considerably reduced because the thermistors are already at an elevated temperature. For example, a 30-horsepower hermetic compressor motor was tested with thermistors that would trip the protection system at 110 degrees C on normal running overloads. With locked rotor and rated voltage from a cold start, tripping occurred in 12 seconds at a peak winding temperature of 159 degrees C. Power was reapplied to the stalled motor after 2.2 minutes at the reset temperature of 95 degrees C; trip then occurred in 4 seconds at a peak temperature of 134 degrees C.

It can be said in summary that PTC thermistors give inverse time-temperature protection instead of the inverse time-current protection that is characteristic of thermal overload relays.

Other Applications

Dc motors have been equipped with PTC thermistors on interpoles and compensating windings to serve alarm or shutdown functions. Wound-rotor ac motors have been supplied with positive thermistors in the stator only. Protection in both cases is on the basis of representative temperature, so these are not ideal applications.

However, thermistors are physically well suited for sensing temperature right in the rotating member of dc motors, wound-rotor motors, and large squirrel-cage motors. Development work now in progress should lead to a practical method for bringing out the signal and thereby extending the range and versatility of the Guardistor motor protection system.



A Transformer To Test Transformers

Careful design is necessary to make certain that a testing transformer can handle future as well as present power transformers.

R. S. Farmer, Design Engineer
Large Power Transformer Division
Westinghouse Electric Corporation
Sharon, Pennsylvania

The two testing transformers shown at left operate singly or could be paralleled to test large EHV transformers.

As power transformers continue to grow in both voltage and kva rating, the problem of testing these large units grows in proportion. The large sizes now being built or contemplated for the future require special testing transformers that are unique designs, especially in their degree of flexibility. This is illustrated in the design of two identical testing transformers now installed in the new power transformer plant at Muncie, Indiana.

General Considerations—To thoroughly test large power transformers, a high-voltage supply and a high-current supply, both single and three phase, must be available—although not necessarily at the same time. For instance, on compromise temperature tests, high currents must be circulated for hours with one or more windings of the transformer under test short-circuited. In this case only the relatively low voltage necessary to circulate this current need be supplied. However, for iron-loss measurements and for over-potential tests, a high voltage must be used but the current required is relatively low. Both of these requirements may be either single or three phase.

Therefore, the testing transformer should have a winding that can supply a large range of high voltages at low currents as well as a large range of low voltages at high currents. This winding connects to the transformer undergoing tests and is referred to as the *load winding*.

A large power transformer undergoing temperature tests is almost a pure reactive load. That is, the percent IX drop is considerably higher than the percent IR drop. Therefore, to counteract this reactive load the designers chose to supply a winding with a wide range of voltages in a large number of steps and with the same kva capacity as the load winding, to connect to a capacitor bank. This winding is referred to as the *capacitor winding*.

The third winding is required to excite the testing transformer and to supply the real power necessary for the IR drop of the transformer under test. This winding is directly connected to a large motor-generator set and is referred to as the *generator winding*.

Thus it was established that three windings would be required and the next step was to pick out the voltage range and the kva capacity for each winding.

Design Factors—The entire shell-form power transformer output for 1957 was reviewed and tabulated for voltage, ampere, and kva values required to completely test these transformers.

Then engineers forecast that three-phase transformers of 1 000 000 kva or more, 750 000 volts, and up to 30 percent impedance, and single-phase units up to 500 000 kva, for use on a 750 000 volt circuit, and up to 30 percent impedance would be built in the future.

On the basis of this information, a decision was made to build two units, which normally would operate singly but could be paralleled to test the extremely large transformers anticipated in the future. Therefore, each testing transformer could be one-half the kva capacity needed to test the largest transformers to be built in the foreseeable future. A value of 125 000 kva was chosen for the capacity of the load winding and the capacitor winding.

The amount of real power necessary for the IR drop in the largest transformer to be tested in the foreseeable future was then calculated, and a value of 20 000 kva was established for the capacity of the generator winding.

The next step was to determine the number of tap changer positions necessary to cover the chosen range of voltages. After examination of available data, the designers decided to make the load winding wye, delta, or reverse delta connected (for single-phase voltages) to test single-phase transformers. These different connections are made by a manual, remote-controlled, motor-operated switch for operation when the testing transformer is de-energized. This load winding is also supplied with series-parallel connections to give, for example, wye voltages of 248 870, 124 430, 82 950, and 41 480 volts. These different series-parallel voltages are also obtained by a manual, remote-controlled, motor-operated switch, operated when the testing transformer is de-energized. This winding is insulated for 825 kv BIL at the line end, but since the winding would also operate in delta at 143 680 volts, the winding insulation could only be graded to 450 kv BIL, which is an insulation class two steps reduced. In addition, since this winding is operated in reverse delta and one of the neutral bushings is connected to the winding at this time (but not connected to ground), then it too must be 450 kv BIL. For conformity, all of the neutral bushings, including those on the potential transformer, are 450 kv BIL bushings.

The line bushings for this load winding are also of a new design. Since these bushings must carry the output of the load winding, namely high voltages at low currents or low voltages at high currents, the bushing must be designed for high voltages and high currents. Therefore, these bushings are designed for 825 kv BIL to match the load winding BIL, and to carry a maximum of 3128 amperes. To accomplish this, a forced-oil-cooled bushing is designed so that when it is carrying high currents a small oil pump mounted on the side of the main transformer tank forces cooling oil through the hollow stud of this bushing, and thus removes the heat generated by the high currents. This oil pump takes insulating oil from the main transformer tank and pumps it, via an insulating tube, to the top of the bushing stud, where it is forced to flow down along the inside of the hollow stud and return to the main transformer tank. There is no interchange of oil from the main tank to the oil used for insulation in the bushing.

The capacitor winding is designed for wye connection for three-phase operation, or reverse delta for single-phase operation. These two connections are made by a manual, remote-controlled, motor-operated switch for operation when the testing transformer is de-energized. This winding is designed for 24 000 volts wye, with plus and minus 12 600 volts variation by a combination of a remote-controlled, motor-operated no-load tap changer and a remote and manually controlled load tap changer. For example, the no-load tap changer can buck or boost the capacitor winding by 7000 volts in four steps total and the load tap changer can buck or boost the capacitor winding by 5600 volts in 32 steps total.

The generator winding receives the output of the generator, which is 13 800 volts. This winding is delta connected because the load winding and capacitor winding are at times operated wye-wye. However, by a combination of two remote-controlled, motor-operated no-load tap changers, one of which operates as a vernier on the other, this 13 800 volts from the generator can be impressed on 50 percent to 100 percent of the winding in 34 steps total. The generator voltage could also be varied, but this was not considered in the design of the testing transformer. As can be seen, the volts per turn of the transformer can be changed from 100 percent to 50 percent in 34 steps; and thus the voltages of the load winding and the capacitor winding will be changed in exactly the same degree, in addition to the voltage variation possible by tap changers and switches located in the other two windings.

By use of tap changers in the generator winding plus the series-parallel switch of the load winding the following voltage positions are available from the load winding:

From 23 940 volts to 287 360 volts in 120 positions in reverse delta;

From 20 730 volts to 248 870 volts in 120 positions in wye;

From 11 970 volts to 143 680 volts in 120 positions in delta.

At the same time, by use of the no-load tap changer and the load tap changer of the capacitor winding, the following voltage positions are available from this winding:

From 6490 volts to 42 210 volts in 5775 positions in reverse delta;

From 5620 volts to 36 560 volts in 5775 positions in wye.

The voltage of the load winding must be measured, so three single-phase, 825-kv BIL potential transformers are mounted within the testing transformer tank.

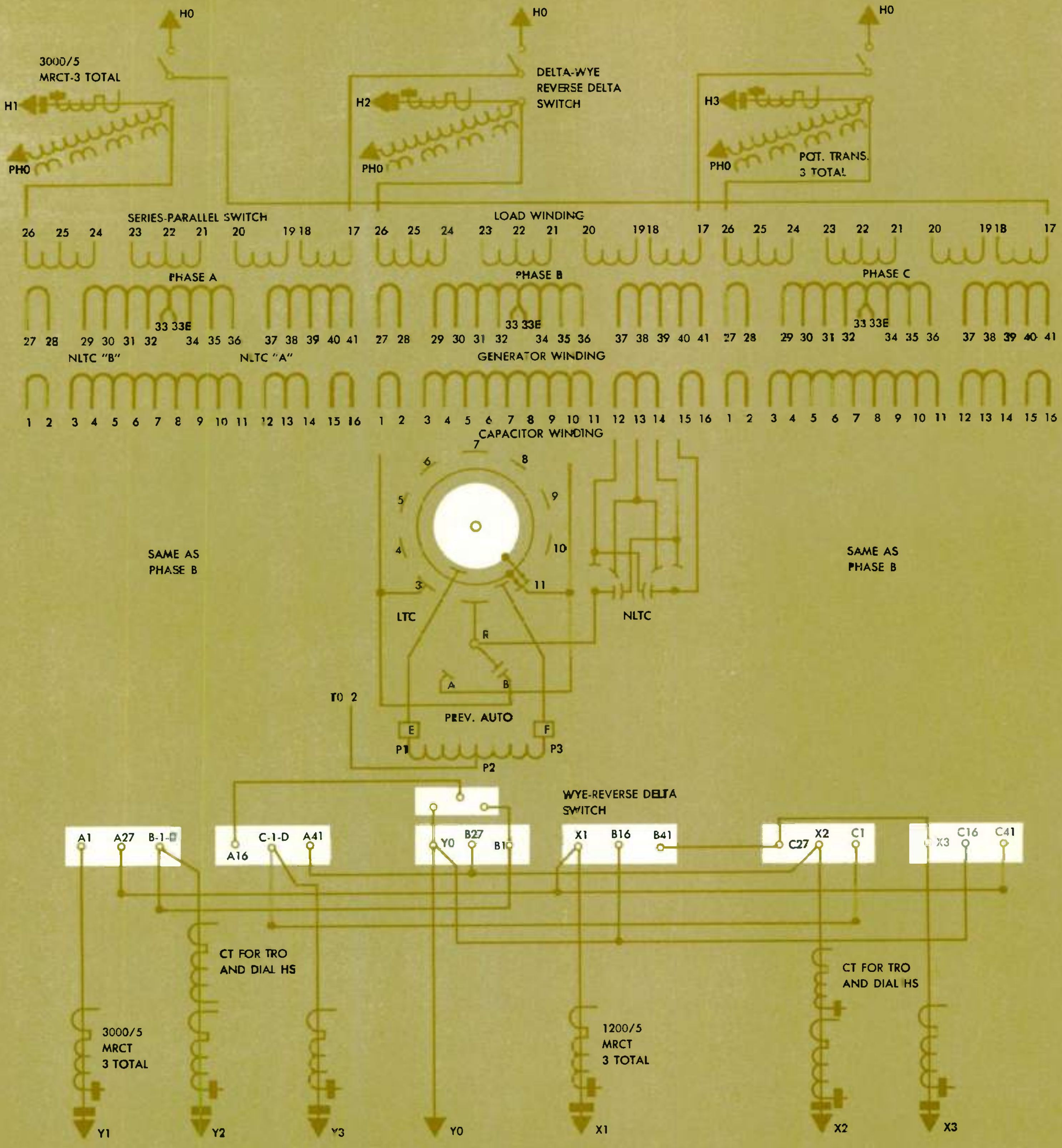
To conserve floor space these transformers are forced oil, water cooled (FOW). The cooling water is supplied from the city water mains since these transformers will not be loaded to full capacity often and the quantity of cooling water required is not excessive.

The factory space limitations and the shipping clearances from Sharon, Pennsylvania, to Muncie, Indiana, were next examined. To conserve floor space, these transformers are designed to be tall but relatively narrow.

With this data in mind, designs were made until the winding shown at right was developed. The design of the core and coils of the transformer was then completed. The load winding series-parallel switch and the load winding wye-delta-reverse-delta switch are housed in a tank mounted on top of the main transformer tank. This upper section also contains the three single-phase potential transformers and mounts the three load winding line bushings, the three load winding neutral bushings and the three potential transformer neutral bushings.

Building the transformer in this manner allowed the lower portion to be shipped on the new Schnable car. The upper section containing the load winding switches was shipped on a 24-inch depressed center car.

The completed transformer, shown on the previous page, weighs approximately 440 tons, is approximately 16 feet wide, 34 feet long and 42 feet high. The tank contains approximately 48 000 gallons of oil. The combination of switches and tap changers make this one of the largest testing transformers ever built.



The Winding Design of the New Test Transformer

LOAD WINDING SWITCHES

Delta	Connects A17-B26; B17-C26; C17-A26
Wye	Connects A17-B17-C17-H0
Reverse Delta	Connects A17-B26; B17-C17-H0

SERIES-PARALLEL SWITCH

Position 4	Connects 24-23; 21-20; 19-18
Position 3	Connects 26-23; 18-24; 20-21; 17-19
Position 2	Connects 26-22; 18-25; 20-21; 17-19
Position 1	Connects 20-22-26-18; 19-21-25-17

CAPACITOR WINDING SWITCH

Wye	Connects A16-Y0
Reverse Delta	Connects A16-B1

AC-DC Marine Propulsion Speed Control System

The efficiency of high-speed ac power generation and the excellent speed control of dc adjustable-voltage systems are combined. This permits use of a gas turbine or other high-speed prime mover to provide a compact propulsion system that is easily controlled and adaptable to automation.

E. C. Mericas
Marine Systems Department
Westinghouse Electric Corporation
East Pittsburgh, Pennsylvania

Electric drive provides maximum flexibility in ship design and operation. It permits the best location of machinery for proper weight distribution within the ship's hull because design is not restricted by the necessity for mechanical ties between the turbine or diesel-engine prime mover and the propeller. The prime mover can operate at its most economical speed and always in one direction because its operation is independent of that of the propeller. This independence also increases prime-mover utilization by enabling the prime mover to drive other generators besides the propulsion generator.

The ac-dc adjustable-voltage electric drive described in this article combines these general advantages with the ability to deliver essentially all the horsepower available from a high-speed prime mover to the propeller over a wide speed range. The drive thus provides high torque at low propeller speeds and unusual maneuverability. These characteristics make the greater cost of the ac-dc electric drive over direct drives economically justifiable for a number of special-purpose ships that need such characteristics.

Drive Considerations

Direct-current drives are superior to any other in speed control, for the adjustable-voltage dc propulsion motor and control provide a large number of speed points down to very low speeds. They are also easily reversible and can be designed with characteristics to fit the application.

However, dc generators are inherently slow-speed machines and therefore cannot be driven directly by modern high-speed turbines and diesel engines. High-ratio reduction gearing can be used, of course, but the gears and the large slow-speed generator negate much of the weight and space saving achieved by selecting a high-speed prime mover. Successful application of a high-speed prime mover requires the use of a high-speed generator.

Alternating-current generators meet this requirement, and their operation at high speeds on shipboard has been proved practical by the steam turbine-electric propulsion system of the T2 tanker. However, the variable-frequency speed control system used in ac-propelled ships does not have the operating flexibility of a dc system. This is not a serious disadvantage for tankers and other cargo and passenger vessels, but it is a distinct disadvantage for such

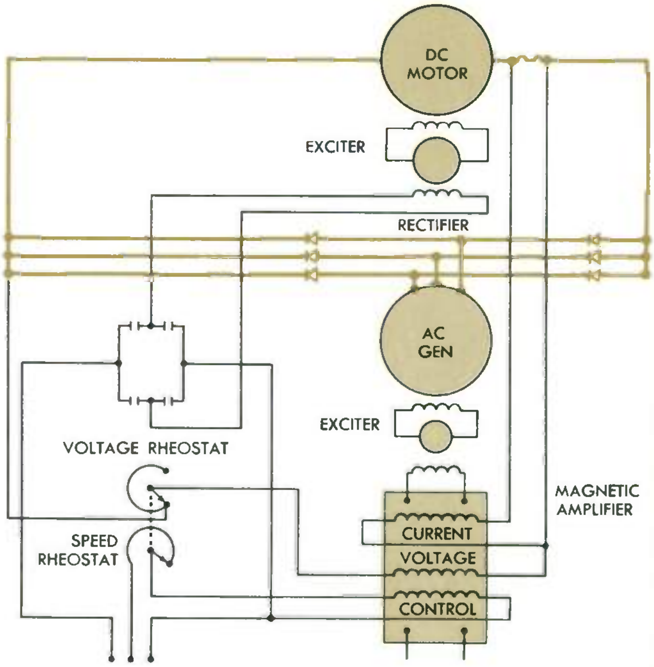


Fig. 1 (Above) Main elements of an ac-dc adjustable-voltage speed control system for marine propulsion. A constant-speed ac generator with excitation control produces variable-voltage power, which is rectified to energize a dc propulsion motor.

Fig. 2 (Right) Performance of the ac-dc system with differential and control windings in its magnetic amplifier is shown by the solid curves. Dashed curves show, for comparison, the performance that would be obtained if control were by current regulation only.

Photo This is the U. S. Army Corps of Engineers seagoing hopper dredge *Markham*. Electric drives permit optimum use of its prime movers as power sources for propulsion, dredging, and auxiliary machinery.

The author has adapted some of this material from his article "AC-DC Adjustable-Voltage Marine Propulsion System" published in the February 1962 issue of the *Journal of the American Society of Naval Engineers, Inc.*

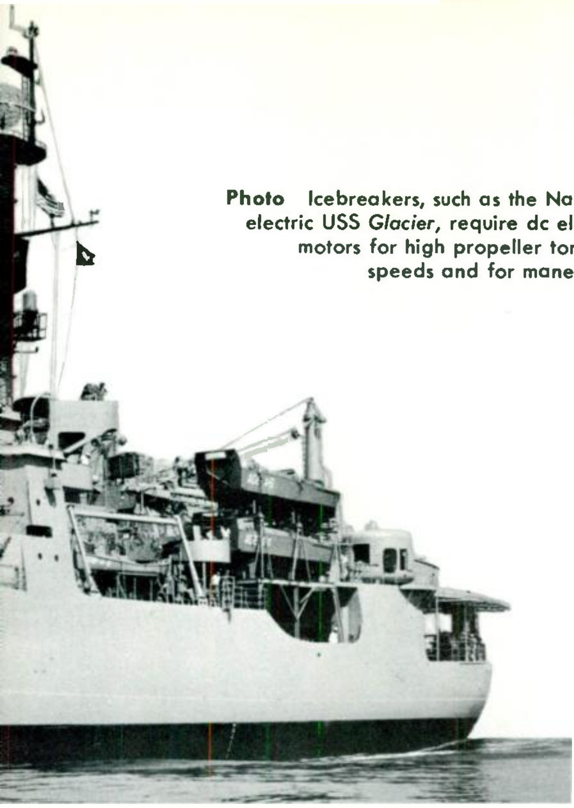
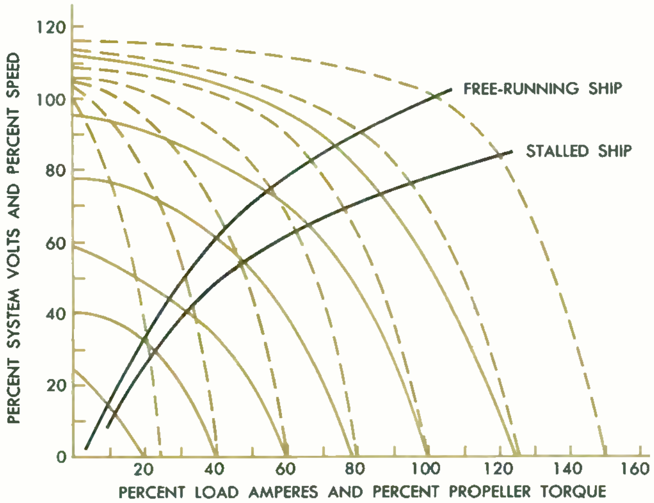


Photo Icebreakers, such as the Navy's diesel-electric USS *Glacier,* require dc electric drive motors for high propeller torque at low speeds and for maneuverability.



special-purpose vessels as tugs, towboats, and dredges.

The ac system is especially limited when used with a gas turbine because of that prime mover's limited speed range. Nevertheless, the gas turbine is a very desirable power source for many vessels because of its light weight, compact design, and simplicity. Also, the gas turbine is readily adaptable to automation because of its simplicity and the small amount of auxiliary machinery required with it.

Successful application of the gas turbine to ship propulsion, then, depends on a system that can efficiently transmit the high-speed power output of the prime mover to a relatively slow-moving propeller and also control speed and direction of rotation. The ac-dc adjustable-voltage system meets this need.

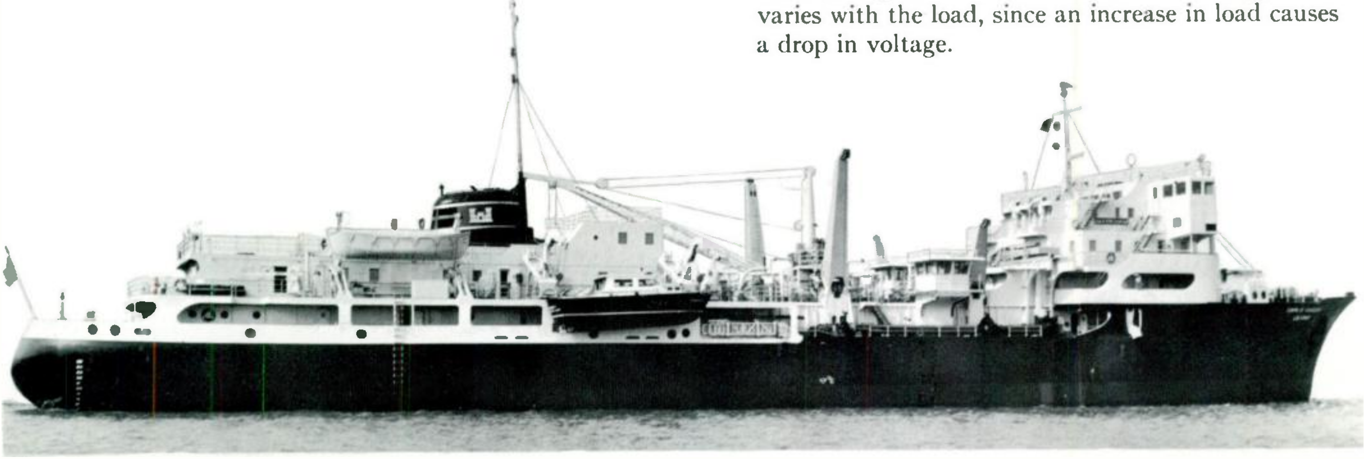
AC-DC System

The economic availability of silicon power rectifiers has made it possible to combine ac and dc machines in a compact system that retains the desirable operating characteristics of a pure dc system while permitting power generation at high rotational speeds. A schematic diagram of such a system is shown in Fig. 1. Its basic components are an ac generator, a magnetic amplifier, a silicon rectifier assembly, and a dc motor.

The ac generator operates at constant speed, but excitation control enables it to produce variable output voltage. This is fed to a rectifier, whose output is then variable-voltage direct current for energizing a dc motor. Motor speed, therefore, is controlled in a manner similar to that in a pure dc system. The motor is reversed by changing the polarity of its separately excited shunt field.

The magnetic amplifier gives the propulsion system constant-horsepower operating characteristics. This regulatory effect is achieved by three signals:

1. The speed control signal originates at the speed rheostat and regulates the magnetic amplifier output. The magnetic amplifier output determines the excitation supplied the generator and thereby controls the generator voltage and propeller speed.
2. The differential current signal originates at the motor commutating field. Its strength is proportional to the load current.
3. The differential voltage signal originates at the rectifier output terminals. The strength of this field is recalibrated by movement of a voltage rheostat when the speed rheostat is turned. Its strength also varies with the load, since an increase in load causes a drop in voltage.



The magnetic amplifier's differential windings (voltage and current) have the same polarity, and their combined ampere-turns oppose the ampere-turns of the speed control winding. A balanced condition exists when the ampere-turns of the speed control winding equal those of the differential windings.

When load current increases, the ampere-turns of the differential windings have a higher value than those of the speed control winding. The resultant decrease in the magnetic saturation effect provided by the control winding decreases the generator voltage and thereby decreases system current until balance has again been restored between speed control and differential windings.

The resultant of the differential windings has a stabilizing effect on operation and at the same time imparts approximate constant-horsepower characteristics to the system. As the speed control handle is moved toward the *off* position, resistance is gradually cut out of the voltage winding circuit by the voltage rheostat coupled to the speed rheostat. The gradual strengthening of the voltage windings compensates for the geometric decrease of the current feedback winding.

The approximate performance of this propulsion system is illustrated in Fig. 2. Constant-horsepower output, maintained by the differential and control windings within the magnetic amplifier, is represented by the solid curves between the free-running and stalled-ship lines. Over the voltage range covered by these curves, propeller torque and load amperes increase in the same ratio as propeller speed decreases, thus maintaining constant horsepower.

The characteristics of the system are such that rapidly drooping generator voltage and motor speed characteristics occur after full load is reached. Maximum load current, even under stalled conditions, is only 150 percent. This built-in current limiting characteristic, imparted by the magnetic amplifier, effectively protects the generator from damaging overloads and thus obviates the need for overload protective devices in the propulsion circuit.

The system regulation curves (voltage vs load current) show the typical dc drive characteristic, in which the curves become very steep as the load current is increased. The dashed curves are included to show the characteristics that would be obtained if control were by current regulation only. The differential voltage winding, with its increased strength at low speed settings, changes the performance to that indicated by the solid curves. These coincide with the dashed curves at zero speed and maximum torque, but they show how the voltage winding effect gives much lower speeds at low torques. The system, thus, is predominantly current regulating on high speed points and predominantly voltage regulating at low speeds.

Applications

The following paragraphs describe some applications in which the ac-dc propulsion system can be used to good advantage.

Tugboats and Towboats—Electric propulsion gives tugs and towboats an outstanding advantage—the ability to utilize full engine horsepower at reduced propeller speed. Tests have demonstrated that a diesel-electric tug with 600 shaft horsepower can perform the same work as a direct-drive diesel tug with 850 shaft horsepower.

Both tugs and towboats must operate in crowded and restricted waters. Pilothouse control—easily obtained with electric drive—provides the accurate and rapid maneuvering required to prevent damage and tow-line breakage.

Ferryboats—Most ferries operate in harbor traffic or other restricted waters where a mistaken signal or delay in executing an order can cause disaster. Electric drive with pilothouse control gives the pilot absolute control of the vessel at all times. The ease with which the electric ferry can be maneuvered makes it possible to increase speeds safely.

In double-ended ferries, electric drive makes it easy to operate the forward motor at reduced speed, so that no resistance is imposed to the movement of the vessel, while the after motor supplies full power. The result is a marked increase in economy over the through-shaft type of double-ended ferry where forward and after screws turn at the same speed.

Dredges—A vessel more suited for electric propulsion than the seagoing hopper dredge can hardly be imagined. The ship's diverse power requirements and the flexibility of electric drives encourage optimum use of the main engines as sources of power for propulsion, dredging, and auxiliary machinery. The diversity of the loads permits use of a prime mover whose rating is smaller than the sum of all the connected generator ratings. Complete pilothouse control with great propulsion maneuverability and wide pump speed control can be provided easily.

Fireboats—Fireboats must have full power available for propulsion while speeding to a fire. When the scene of the fire is reached, however, the pumps demand most of the power, with a small amount of propulsion power reserved for maneuvering the boat. Electric drive easily satisfies these conditions, and the electric fireboat is instantly available for getting under way with practically no standby expense. Pilothouse control is invaluable in maneuvering and holding position when fighting a fire.

Icebreakers—Icebreakers require maximum horsepower at low propeller speed when breaking ice, and rapid maneuverability also is essential. Electric drive has established itself with the U. S. Navy and Coast Guard as the only type that meets these requirements.

Oceanographic Survey Vessels—Survey vessels and other ships operated by the Government as aids to navigation and in oceanographic research require the utmost in maneuverability. The wide control range of electric drive and the speed with which control can be applied provide this maneuverability.

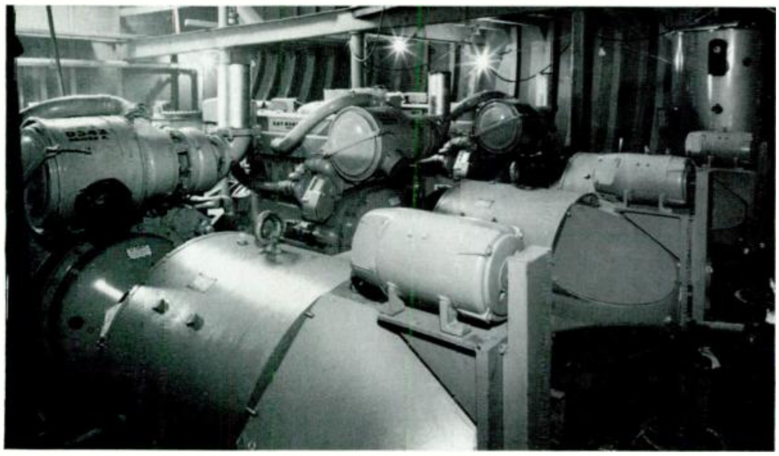
Salvage and Rescue Ships—These, like fireboats, require large amounts of propulsion power in going to the scene of an accident. Once on location, however, only small amounts of power are required for salvage and rescue machinery. Electric drive meets these requirements.

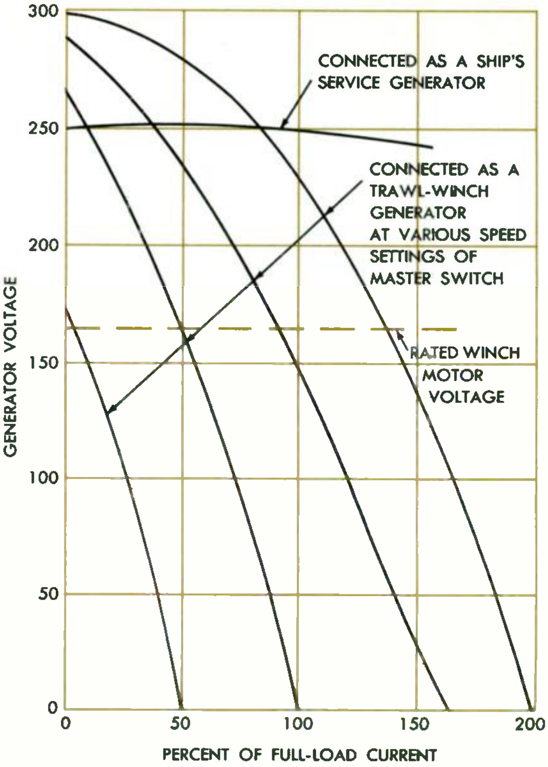
Fishing Vessels—The maneuverability and flexibility provided by electric drive improve operating economy in trawlers and draggers. In tuna clippers having mechanical refrigeration, electric drive provides a generating plant that can be used to supply the refrigeration load. Generating capacity is easily proportioned between propulsion and refrigeration on the return to port after the catch has been made, when maximum speed is not necessary so long as refrigeration is maintained.

TECHNOLOGY IN PROGRESS

Photo The three ship's service diesel generators in the research vessel are shown during construction in the Southern Shipbuilding Corporation yard at Slidell, Louisiana. One generator is conventional; the other two can either power the trawl winch and bow thruster or supply ship's service power.

Graph Dual-purpose generator voltage characteristics.





Dual-Purpose Generators For Fisheries Research Vessel

A multipurpose ship's electric power system is one of the features of *Albatross IV*, a versatile research vessel being built for the U. S. Fish and Wildlife Service.

Three Westinghouse 150-kw, 250/125-volt, three-wire, compound-wound diesel generators will supply dc ship's service power. One of these generators is a conventional ship's service generator producing constant-voltage power for the power and lighting system. The other two are dual-purpose machines that will provide adjustable-voltage power for the motors driving the main trawl winch and the bow-thruster propeller. When not required for these duties, the dual-purpose generators can supply power to the ship's service system in parallel with the conventional generator. This provides a reserve of generator capacity for the large amount of electronic equipment needed on a research vessel.

Ordinarily, the characteristics required of a flat compounded dc ship's service generator and an adjustable-voltage trawl-winch generator differ widely. The ship's service generator must maintain essentially constant voltage regardless of load, and there must be equalizer connections between generators for parallel operation. The trawl-winch generator must have characteristics that will permit the winch motor to stall or reverse if the trawl lines snag. Voltage characteristics of the special generator fit both types of duty.

The generator rating was selected according to the needs of the ship's service plant and is more than required to power the 125-horsepower winch motor. This overrating permitted selection of a lower-than-standard voltage (165 volts) for the winch motor so that the full-load current of the motor is approximately the same as that of the generator. It also provides the high no-load speed required for the motor without the need for enlarging the generator.

The generator for the bow thruster has the same characteristics as the trawl-winch generator to keep the installation simple, although normally it would be designed with only enough voltage droop to stabilize the motor. (The bow thruster is a propeller mounted in a transverse tunnel in the bow of the ship below the waterline. It is used for changing the heading of the ship at very low speeds, when the rudder has little effect.)

For ship's service duty, the generator series fields are connected with cumulative polarity to increase excitation with load and provide a full-load voltage the same as the no-load voltage. The series field has more turns per pole than are required, so a large part of the load current is bypassed through a resistor connected across the series field winding. The amount of resistance is selected to provide the amount of cumulative ampere-turns in the series field required for flat compounding of the generator. Equalizer and neutral connections are made at the generator switchboard. An attached exciter energizes the generator's separately excited shunt field; its self-excited shunt field is not used.

For trawl-winch or bow-thruster duty, the leads to the generator switchboard are disconnected, the series field polarity is reversed from cumulative to differential, the series field bypass resistor is disconnected, and the generator is connected to the armature terminals of the motor. The excitation scheme is then the standard three-field arrangement commonly used on power shovels and draglines. With the resistor disconnected, the series field carries all of the generator current and is strongly differential. The generator provides part of its own shunt excitation with a self-excited field, and the remainder comes from the exciter.

The trawl-winch and bow-thruster motors are controlled and reversed by master switches and rheostats in the shunt fields of their generator exciters. Power for control and for motor excitation is taken from the ship's service dc bus.

Albatross IV was designed by Dwight Simpson and Associates and is being built by Southern Shipbuilding Corporation. ■ ■ ■

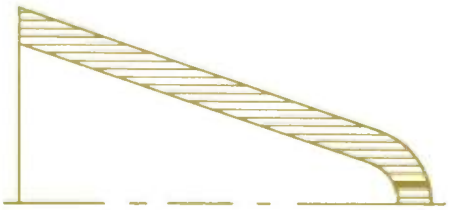
Economical Method Produces High-Temperature Components

Ablative heat shields for ballistic re-entry bodies can be in production in less than 30 days from final design with a technique, called lapwinding, that dispenses with molds and dies. The method consists of winding a resin-impregnated tape onto a mandrel or onto a substructure of metal or plastic. Tapes made from glass and asbestos have been used successfully; other kinds could also be used. After curing, the heat shield is machined to the desired contours.

The laminations are parallel to the longitudinal axis of the re-entry body (see illustration). This orientation of the reinforcing fibers (which conduct heat better than the plastic) makes a long heat-conducting path and thereby delays transmission of heat to the interior of the re-entry body. Other advantages of the process are virtual elimination of tooling cost, small amount of machining required, short lead time, and ability to form a part of any size in one piece.

The technique is similar to the tube-winding process used to make electrical insulators and coil forms. A hot roll melts the resin in the impregnated tape just before it is wound onto the mandrel, and the same roll applies heat and pressure to the material as it is wound. The process was developed by the Westinghouse Micarta Division with the Army Ballistic Missile Agency. It is adaptable to production of rocket nozzles as well as heat shields. It can also be used for producing chemical- and heat-resistant industrial parts of conical or hemispherical shape without expensive molds or hand layup. ■ ■ ■

Longitudinal section of a re-entry heat shield shows how lapwinding orients the laminations parallel to the shield's axis to make a long heat-conducting path.



Static Inverter for Navy

A 75-kva static inverter developed for the Bureau of Ships, U. S. Navy, uses Trinistor controlled rectifiers as its switching elements. It changes dc input power with voltage ranging from 210 to 355 volts to 400-cycle ac power having voltage and frequency regulated to within one percent. The output waveform has less than five percent harmonic distortion.

Conversion of direct current to 400-cycle alternating current is usually accomplished on shipboard by motor-generator sets. The new system was developed to test the feasibility of replacing motor-generator sets in submarines, where noise and vibration must be kept to a minimum.

The inverter would provide alternating current from the submarine's batteries or from the source that charges the batteries. Considerable amounts of 400-cycle power are needed for a submarine's vital electronic systems, and it must be available even when the vessel lies motionless and submerged to escape detection. ■ ■ ■

Faster and More Versatile Computer Process Controllers

A versatile family of automatic process-control systems, the Prodac 500 Series, employs a high-speed digital computer designed specifically for on-line control of complex industrial and utility processes. The computer's complete read-write cycle time is 4 microseconds, and it can perform more than 100 000 calculations a second. This speed and the flexibility of the input-output equipment (which allows the memory to be shared by the arithmetic unit and many peripheral input and control devices) make the systems among the most advanced in the control field

High speed and priority-interruption provisions enable the computer to control primary process systems, control subsystems, and perform off-line computations concurrently. The process-control programs automatically interrupt lower-priority programs (such as data accumulation and reduction) so that the computer can serve the immediate needs of the process and still work at maximum capacity.

Core memories are random-access modules in capacities ranging from 4096 eighteen-bit words to 16 384 words. Capacities of the drum-type mass memories available are 32 768 and 65 536 eighteen-bit words.

The first two control systems in the new series are the Prodac 510 and the Prodac 580. Both have identical standard components, a common language, and identical programming. The main difference is that the Prodac 580 is larger and more flexible than the Prodac 510, and its throughput capacity (capacity to process diverse information simultaneously) is correspondingly greater.

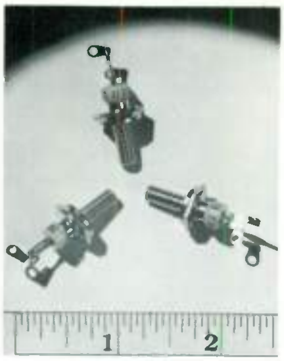
The Prodac 510 will be used primarily for controlling single-process systems and for data-logging, monitoring, and computing in electric utility systems. The Prodac 580 will be used for computer control of automatic steam plants, rolling mills, and applications where several processes are controlled by a single computer.

The new control systems are the result of a joint development program undertaken by Westinghouse and the UNIVAC Division of Sperry Rand Corporation. The central computer units and some of the input-output devices are manufactured by UNIVAC; the complete control systems incorporating the computers are supplied, installed, and serviced by Westinghouse Industrial Systems. ■ ■ ■

On-Line Computer Control For Arizona Public Service

An on-line closed-loop Automatic Digital Dispatch and Processing System (ADDAPS) soon will economically regulate output of all generating units on the combined systems of Arizona Public Service Company and the Salt River Power District. It also will provide economy interchange information for coming power interchange transactions between the utility, the Salt River Power District, and neighboring utilities; log system performance and operating data; monitor

PRODUCTS FOR INDUSTRY



7.4-AMPERE TRINISTOR CONTROLLED RECTIFIER LINE (JEDEC series 2N-1770) serves low-power industrial applications. Forward blocking voltage ratings are 25 through 400 volts, and transient peak reverse voltage ratings are 35 through 500 volts. Thermal impedance is 2.5 degrees C per watt. Typical applications are in proportional control circuits, such as heating, light dimming, and dc motor control systems.
Westinghouse Semiconductor Division, Youngwood, Pa.

THERMOELECTRIC EDUCATIONAL UNIT demonstrates principles of thermoelectric cooling and generation. It consists of a bismuth-telluride couple mounted on a heat sink, a heating resistor, embedded thermocouples for temperature measurements, and binding posts for connections. Resistivities of the couple legs, Seebeck coefficients, thermal conductivities, figure of merit, and heat-pumping performance can be measured. Experiments are suggested in a manual.
Westinghouse Semiconductor Division, Youngwood, Pa.

MEMORY LATCHING ATTACHMENT that simplifies design of relay control systems has been added to the four-pole BF relay line. Power requirement for unlatching is 24 volt-amperes ac. The latch can be operated manually for circuit testing. Clamps attach the latch to the regular BF relay, and it can be added or removed at any time.
Westinghouse Standard Control Division, Beaver, Pa.

MOTORS WITH SHORT AXIAL DIMENSION—called pancake motors—are designed for use where conventionally shaped motors won't fit. Speed ratings range from 4000 to 12 000 rpm, and the motors are available with either high or low slip. They operate on 115/200-volt 400-cycle power, three-phase or single-phase. The new motors have stainless-steel shafts, locked front bearings, aluminum housings, and synthetic-enameled wire.
Westinghouse Aerospace Electrical Division, P. O. Box 989, Lima, Ohio.

and control unattended substations; assist in selection of optimum combination of generating units to be run; forecast system load; check system security; optimize spinning reserve; and perform off-line calculations.

The system is the most sophisticated yet to be applied in utility system operation. Its extremely high computational speed enables it to solve problems previously beyond the capacity of on-line computers, and it has considerable excess capacity for solving new or more complex problems in the future. The system is expected to be in operation late in 1963.

ADDAPS will be programmed first to handle such problems as control and economic dispatch, optimization of generating capacity of unit commitment, economy interchange billing, energy accounting, maintenance scheduling, on-line power flow study, loss formula calculations, and short-circuit calculations. Future uses include on-line outage diagnosis and coordination of system control computer with plant process computers.

ADDAPS has two basic parts: a solid-state analog system that regulates generators to meet load fluctuations, and a Prodac 580 digital computer system that continuously provides economic information and performs the functions listed above.

Analog System—This system measures net interchange and system frequency to determine the error in total generation. The error is divided among the machines under regulation in accordance with the dispatcher's preset instructions. Change-load signals are sent to individual machines, causing them to increase or decrease their outputs. Actual generation signals are sent back to the dispatching office to insure proper generator loading.

Maximum and minimum generator kilowatt limits insure that machines operate continuously within their safe capabilities. Maximum and minimum economic limits are also provided. In addition, the operator can set the base economic load for the machines if the computer is not functioning.

Effective coordination between the digital and analog equipment will minimize difficulties in transferring between manual and computer operation. For example, the computer outputs base economic generation for individual machines by changing the manual adjustments automatically so that there can be no error in this quantity when transfers are made.

Digital System—The Prodac 580 computer system will have 223 analog and 378 digital inputs and will output 254 quantities. Extremely fast computational speed will enable the computer to solve even more sophisticated control problems than those normally handled in systems operations today. (See "Faster and More Versatile Computer Process Controllers.") ■ ■ ■

Above A new transformer-rectifier power supply is constructed mainly from standard motor parts to minimize cost. The design also makes the unit compact and light.

The transformer's primary and secondary are wound on the stator of an induction motor. The primary winding serves also as a motor winding and drives a rotor with an attached fan for cooling the rectifier and other components. Silicon diodes housed in the motor frame make up the rectifier.

The unit is suited to many applications that can use nonregulated direct current, especially those that require a totally enclosed self-cooled power supply. The initial model operates on 400-cycle three-phase current and is supplied in ratings from 10 to 150 amperes.

Solid-State Acoustic Flowmeter

A new flowmeter determines speed and direction of underwater currents by measuring the time it takes for sound to travel between pairs of acoustic transducers. (Sound travels faster with the current than it does against the current.) The transducers are mounted on a probe (see photo) that can be anchored to the ocean floor, attached to a pier, or lowered from the surface. A cable connects the probe to its power supply and to its recording instrument.

The flowmeter has no moving parts, is completely transistorized, and can measure flow rates of a small fraction of a knot. It was developed to provide a more reliable instrument than conventional mechanical flowmeters actuated by propellers or rotating vanes.

The acoustic flowmeter is an outgrowth of work done for the U. S. Navy by the Westinghouse Research Laboratories and Ordnance Division. It is expected to be especially useful for mapping currents in rivers and harbors. With precise information on currents, engineers may be able to prevent heavy sand and silt accumulation and control the course of rivers. The instrument also should be useful in determining the best locations for harbors and beaches.

The principle used in the flowmeter has also been applied in instruments that measure the speed of ships and the flow of liquids in pipelines. ■ ■ ■

Below The spherical transducer array in the foreground is one type of sensing probe used with the acoustic flowmeter. It enables the flowmeter to measure speed and direction of currents in three dimensions simultaneously. Behind it are the recording instrument and power supply.

First 96-Kilomegacycle Maser

The first operating 96-kilomegacycle (10^9) maser with a pump frequency of only 65 kmc has been developed by Westinghouse under contract to the Air Force's Electronic Technology Laboratory, Wright-Patterson Air Force Base. This is the first time microwave amplification by maser principles has been achieved at this high frequency, and also the first time that low-frequency pumping has been achieved with as large a ratio between signal and pump. A gain of 10 decibels has been demonstrated, and continued development is expected to yield higher gain with noise figures of less than two db.

The new pumping technique uses five paramagnetic spin energy levels to obtain inversion, with pump frequency lower than signal frequency, so that operating frequency of millimeter wave masers is no longer restricted by pump source frequency. Most masers have had to be pumped at twice their operating frequency to achieve low noise amplification.

The 96-kmc maser operates at two degrees K and uses iron-doped titanium oxide (rutile) as the active maser material. Potential applications include radiometry, radar, and space communication. ■ ■ ■

NEW LITERATURE

Westinghouse Thermoelectric Handbook, written primarily to increase engineers' understanding of thermoelectric cooling and heating phenomena and to help them solve application problems. It discusses thermoelectric theory and materials, heat-pump module characteristics, testing, device design, and applications. Power supplies, temperature control, temperature measurement, and heat sinks are also described and illustrated. Proposed standard definitions are presented, as well as symbols, constants, units, and conversion factors. Price $2.00.

Westinghouse Semiconductor Division, Youngwood, Pa.

Movable Partitions, a booklet describing the movable partitions for commercial and office buildings made by Architectural Systems, Inc., a wholly owned subsidiary of the Westinghouse Electric Corporation. It describes the many options in panel cores, panel sizes, doors, glazing and hardware. It also gives technical data on the partitions, accessories, and method of installation.

Architectural Systems, Inc., 4300 36th Street, S.E., Grand Rapids 8, Mich.

Integrated Heat Transfer Systems, a booklet describing heat transfer systems made up of radial-flow condensers, feedwater heaters, and flash evaporators. Information on circulating pumps, air removal equipment, and other auxiliaries also is given.

Westinghouse Electric Corporation,
P. O. Box 2099, Pittsburgh, Pa.

ABOUT THE AUTHORS

R. M. Sando, A. T. Monheit, and **C. I. Denton** authored the article on satellite rendezvous techniques. Sando, who has a Bachelor of Aeronautical Engineering degree from New York University (1942), came with the Air Arm Division of Westinghouse in 1952, after 10 years of aircraft design with another company. He is presently a Fellow Engineer on the staff of the manager of the mechanical design and development department, where he serves in an advisory capacity in the field of mechanical and aeronautical engineering.

Monheit, who has a BSEE from City College of New York (1950) and an MS from Harvard University (1951), came directly to the Air Arm Division from Harvard. He has worked on autopilot systems, jet engine controls, missile radar seeker systems, and most recently, aerospace applications. He is presently a Fellow Engineer, assigned to the systems formulation staff of aerospace program engineering.

Denton is a graduate of West Virginia University (1950) with a BSME, and has an MS from the University of Maryland (1959). He joined the Air Arm Division in 1954, and has worked on the mechanical design of airborne electronics equipment. He is a Senior Engineer in mechanical design and development engineering, working on the mechanical design and fabrication of spacecraft.

In this issue, **Edwin G. Noyes, Robert L. Richards,** and **John D. Davidson** have pooled their writing efforts on the subject that they have been pooling their design talents on—developing and adapting steam turbine generator unit designs for computer control.

Noyes, a Texas A & M College graduate in ME (1948), came with Westinghouse on the Graduate Student Course and was assigned to the Steam Division, where he became a steam turbine design engineer. In 1957, he was made a supervisory engineer in charge of steam turbine controls. In late 1961, Noyes was appointed manager of the control engineering section, where he is responsible for the design, development, and application of control systems for large and medium sized turbines.

Richards, an EE graduate of the Pennsylvania Military College (1949), joined Westinghouse in 1951. His first assignment was in the large turbine mechanical design section, where he was responsible for the design and application of all turbine electrical appurtenances. Presently a Senior Engineer, he has these same responsibilities in the customer order engineering control section of the large and medium turbine department.

Davidson, an EE graduate of the University of Colorado (1942), is the generator representative on the team. Davidson spent his first 2½ years with Westinghouse as an electrical tester of large rotating apparatus, followed by 6½ years as a design engineer in dc motor and generator engineering. His next assignment for three years was shop foreman of a rotating machine assembly section. He returned to engineering design, and spent two years in induction regulator engineering. In 1956, he moved to turbine generator engineering, and is presently a Supervisory Engineer, primarily concerned with the application of turbine generators.

B. E. Lenehan came with Westinghouse on the Graduate Student Course directly upon graduation from the Carnegie Institute of Technology with a BSEE (1921). After completing Westinghouse Design School, Lenehan became an instrument design engineer. His success is evidenced by some 60 patents in such areas as electric instruments, timing devices, protective relays, watthour meters, and power-line carrier equipment. Lenehan is presently a Consulting Engineer, concerned with advanced development and design in the Relay-Instrument Division.

J. T. Wintermute, who joins Lenehan in describing the torque-balance transducer, joined Westinghouse in 1940. He obtained his BSEE from the Newark College of Engineering in 1950. Wintermute's major responsibilities have been in the design of indicating instruments. He is presently a Design Engineer in the Relay-Instrument Division.

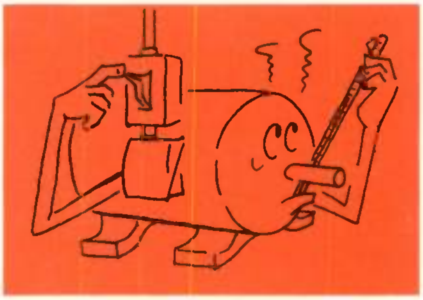
John J. Courtin graduated from Villanova University with a bachelor's degree in electrical engineering in 1938. He served as an inspector of Naval material during World War II and then, in 1945, joined the Westinghouse Motor and Gearing Division at East Pittsburgh. He moved with the Division to Buffalo the following year. He has been engaged in motor development and application there, including the development of part-winding starting arrangements, ac mine motors conforming to U. S. Bureau of Mines standards, and the Guardistor motor protection system described in this issue. Courtin is a Senior Engineer in the advanced development section.

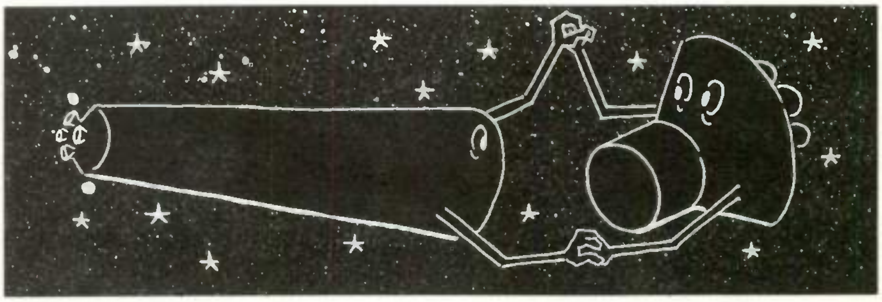
As the design engineer in charge of the testing transformers described on page 119, **R. S. Farmer** knows well the problems involved in designing such a large but flexible unit. Farmer has been a design engineer in the large power transformer group since he joined the Transformer Divisions in 1947.

A native of Charleston, South Carolina, Farmer moved to Pensacola, Florida at the age of six. After completing elementary and high school, he returned to his native state to attend Clemson College, where he earned his BS degree in engineering in 1942. After four years in the U. S. Navy as a torpedo officer, he joined Westinghouse on the Graduate Student Course in 1946; after several assignments, he moved to the power transformer group.

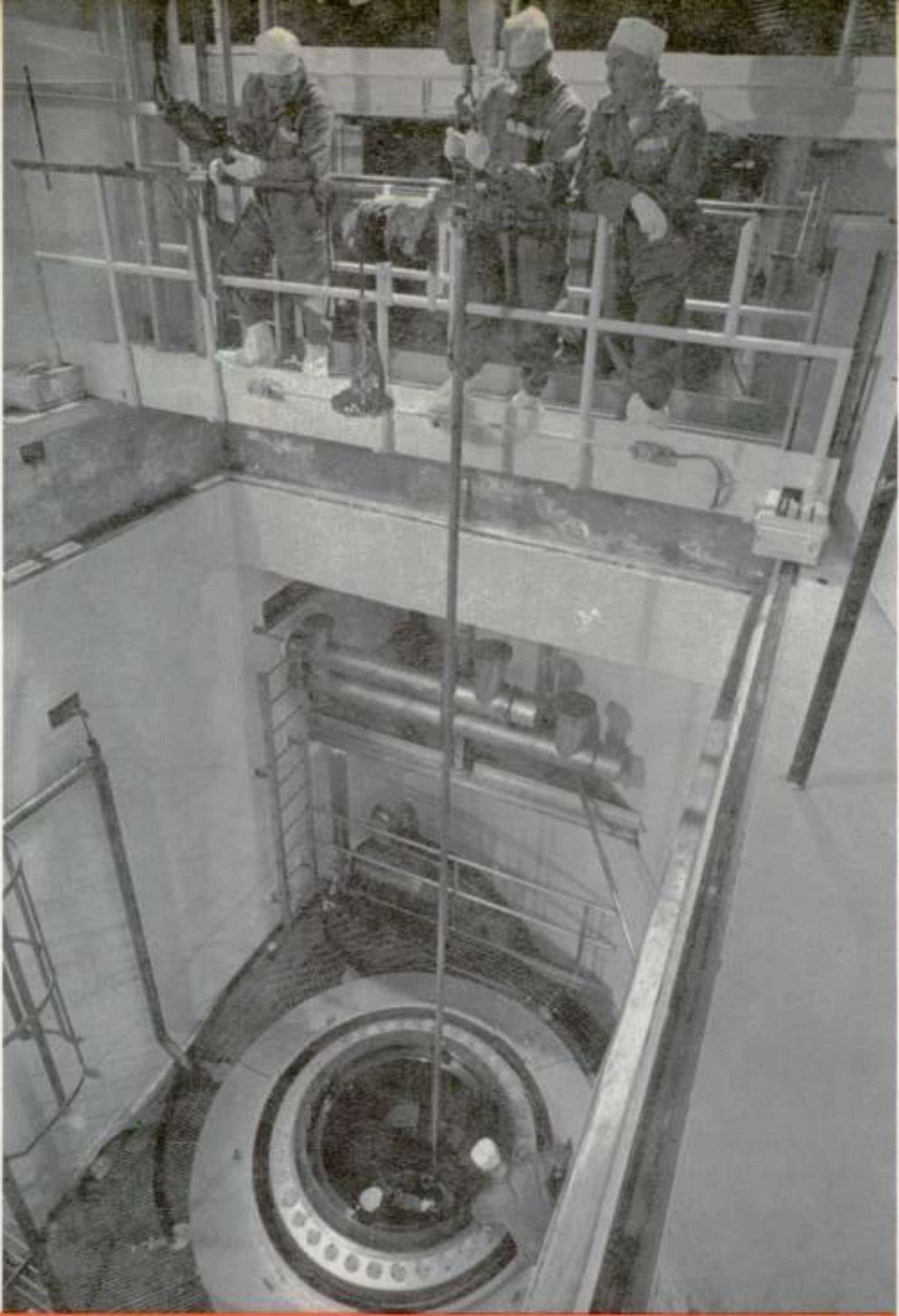
E. C. Mericas is especially interested in advanced drive and control systems for ships. He is a member of the Society of Naval Architects and Marine Engineers, a commander in the U. S. Naval Reserve, and commanding officer of Naval Reserve Military Sea Transportation Company 4-4.

Mericas graduated from the U. S. Merchant Marine Academy in 1944 with a BS degree. He has also completed the Reserve Officers' Command and Staff Course and has attended the Naval War College. He served as an officer in the Navy in World War II and as a merchant marine officer from 1947 to 1951. He then worked as a marine engineer with Creole Petroleum Corporation in Venezuela before joining Westinghouse in 1957. He is now a marine engineer in the Marine Systems Department.





The Saxton Nuclear Experimental Corporation's reactor, shown here during fuel loading, will operate for about 15 months on the energy supplied by about one ton of nuclear fuel. In addition to being a proving ground for advanced concepts and techniques, the reactor will supply steam to a nearby generating station.



This view, looking up from inside the Saxton reactor's pressure vessel, shows the loading of a fuel assembly. The reactor now holds 21 such assemblies. The plant went critical in April 1962.